Forestry Sector Technical Work Group
Policy Option Recommendations

Summary List of Policy Option Recommendations

	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2020* (Million $)	Cost-Effective-ness ($/$tCO_2e$)
		2012	2020	Total 2008-2020		
F-1	Improved Forest Health	0.5	0.5	7.0	-$376	-$54
F-2	Reduced Conversion to Nonforest Cover	1.1	4.7	26.8	$556	$22
F-3	Enhanced Carbon Sequestration in Forests	0.2	0.6	4.0	$107	$26
F-4	Enhanced Carbon Sequestration in Harvested Wood Products	0.01	0.01	0.1	*Quantified in coordination with F-3*	
F-5	Expanded Use of Wood Products for Building Materials	*Not quantified*				
F-6	Expanded Use of Biomass Feedstocks for Electricity, Heat and Steam Production	0.1	0.6	3.4	-$85	-$25
F-7	Improved Commercialization of Advanced Lignocellulosic Processes	0.02	0.9	3.7	$261	$70
F-8	Expanded Urban and Community Forests	0.1	0.2	1.4	-$165	-$122
	Sector Total After Adjusting for Overlaps**	**2.0**	**7.5**	**46.4**	**$298**	

* All costs are reported in 2006 constant dollars, net present value is calculated using a 5% real discount rate. For more information on quantification methods, see http://www.ecy.wa.gov/climatechange/CATdocs/100407Policy_Option_Quantification_Methods.pdf.

** Note that the emissions reduction and cost estimates shown for each individual option presume that each option is implemented alone. Many options interact extensively, as they target the reduction of energy use or emissions from the same sources. Therefore, if multiple options are implemented, the results will not simply be the sum of geach individual option result. After individual option assessments were complete, a "combined policies" assessment was conducted to estimate total emission reductions, and to capture the overlaps among policies that are reported here.

Note: Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost **savings** associated with the options. Also note that totals in some columns may not add to the totals shown due to rounding.

F-1 Improved Forest Health

Mitigation Option Description

Reduce catastrophic wildfire GHG emissions due to fuels buildup attributable to decades of fire suppression and related pest infestation and disease. Annually wildfire contributes at least 0.18 $MMTCO_2e$/yr, or 0.2% of the state total (Westcarb I, 2007*).

Implicit within this mitigation option is the recognition that:

- Wildfires play an important ecological function in the natural forest lifecycle yet millions of acres of Washington's forestlands are at uncharacteristic risk due to past management practices.
- Forests, depending on how they are managed, may be a net source or a net reservoir of CO_2.
- Eastern and Western Washington have unique forestland types and related forest health challenges and should be treated differently.
- Implementation methods must be balanced and integrated with other policy options including those focused on carbon sequestration, biofuels and feedstocks, conversion and afforestation.

Through incentive and regulatory programs that reduce uncharacteristic wildfire this proposed option will promote hazardous fuel reduction in forests, and subsequent use of fuels in biomass power plants.

***** *This figure was the average for the years from 1990 through 1996, a period which preceded the larger fire seasons recently experienced. Current and projected emissions are likely to be significantly greater in the baseline case, and validation is needed for the methodology*

Mitigation Option Design

Goals:

Reduce the rate of wildfire volatized GHG emissions through treatment of 28,692 acres/year of forestland acres "at-risk" of catastrophic wildfire;

Restore 25% (373,000 acres) of Washington's "at-risk" state and private forestland in NE Washington to a characteristically healthy state by the year 2020;

Restore 50% (746,000 acres) Washington's "at-risk" state and private forestland to a characteristically healthy state by the year 2035;

Restore all 1.5 million acres of Washington's "at risk" state and private forestland to a characteristically healthy state by the year 2050;

Timing: See goals above.

Coverage of parties: Private forestland owners and managers, State-owned forest land managers, USDA Forest Service.

Other: While not addressed directly by this option, goals directing future reforestation of forests burned by uncharacteristically severe wildfires could provide additional GHG benefits through enhance carbon sequestration in forests. Wildfire of uncharacteristic size and severity may retard reforestation from seeds on-site or dispersed from surrounding forests. Currently, Washington does not require landowners to reforest following fire, based on the assumption that natural reseeding will be sufficient. However, extensive burns in Washington State history (eg: the 1902 Yacolt Burn which destroyed about 240,000 acres in SW Washington) have been followed by decades of reforestation failure. Targeted efforts at reforestation after severe and extensive fires would potentially accelerate the resumption of forest sequestration, providing additional near term carbon benefits.

Implementation Mechanisms

Enhanced coordination of state management plans with federal and tribal forestland management through joint planning activities and participation on advisory committees. The jurisdiction of Implementation Mechanisms outline below cover private and state timberlands. The Colville and Yakama tribes have been have been actively employing forest health treatments that serve as a good model.

Consideration should be given to opportunities to influence "forest health" on Federal Forestlands. The GHG reduction potential of this option would increase if the USFS adopted similar goals to reduce "at-risk" Federal forestland. (See the Biomass Feedstock Supply Analysis in an Appendix to this document for USFS estimates of the potential for thinning treatments on federal lands.)

While we assigned a higher priority to recommendations focused on thinning, we do recognize all forms of "Forest Health Treatments" like prescribed burns, integrated pest management. We feel strategic thinning and similar treatments are most prudent in the climate policy context.

A list of specific mechanisms is provided below:

- Enhanced Research and Information Dissemination*
    - Education to landowners etc.
- Technical Assistance*
    - Pilot Projects
    - Professional advise to land owner
    - Modeling
- Regulatory Forest Health Orders*
    - For extreme risk situations
- Financial Assistance
    - For landowners to implement forest health treatments
- Stimulate markets

  - Seed demand for small diameter material through biomass and other markets
  - Position forest health treatments to be sold as carbon credits in anticipated carbon cap and trade market
  - Target areas that "pencil" in economic terms first to buy time for infrastructure and other economic limitations to be resolved
- Public Works Project
  - WA DNR becomes involved in improving forest health using savings from wildfire management season
- Fire control protocols that reduce GHG emissions in fire fighting
- Collaborative stakeholder planning processes
  - E.g. NE WA Forestry Coalition developing consensus-based approaches to influencing policies on Federal Lands (Colville NF)

Existing statutory authority, under way or under development but may benefit from additional resources/authority/incentives. Specifically, we recommend:

- Maintaining or increasing base funding level for new forest health program at DNR.
- A broad range of pilot projects for silvicultural thinning regimes, evaluate these pilots and disseminate findings and appropriate models to landowners
- Establishing a strong staff/technical support presence in Eastern Washington

Related Policies/Programs in Place

DNR Forest Health Program, RCW 76.06, http://apps.leg.wa.gov/RCW/default.aspx?cite=76.06, updated in 2007 with SSB 6141, http://www.leg.wa.gov/pub/billinfo/2007-08/Pdf/Bills/Session%20Law%202007/6141-S.SL.pdf

Types(s) of GHG Reductions

Potential near term reductions in fire-related CO_2 emissions from avoided wildfires

Increased carbon sequestration from enhanced forest growth (not quantified)

Displaced fossil fuel emissions from biomass energy (quantified under F-6 and F-7)

Estimated GHG Savings (in 2020) and Costs per Mt CO_2e

			Reductions		$(MMtCO_2e)$*		
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) $ millions**	**Cost-Effective-ness $/tCO_2$**
F-1	Improved Forest Health	Restore 25% of forests at high fire risk by 2020	0.5	0.5	7	-$376	-$54

Data Sources

Front Range Fuels Treatment Partnership Final Report 2006. Data provided by Washington Department of Natural Resources, Community Assistance and Fire Prevention on fire condition status of WA forests and costs of wildfire treatments. B. Lippke, J. Comnick, and L. Mason, June 2006. Alternative Landscape Fuel Removal Scenarios: Impacts of Treatment Thinning Intensity and Implementation Schedules on Fire Hazard Reduction Effectiveness, Carbon Storage, and Economics. RTI/CORRIM Joint Working Paper No. 6.

Quantification Methods

Forest fire mitigation involves reducing the amount of fuel (i.e., live and dead biomass) in the forest to decrease the risk of future wildfires. Forest fire mitigation can impact greenhouse gas emissions and carbon sequestration in several ways. Forest biomass can be physically removed or it can be combusted using controlled prescribed fires. When biomass is mechanically removed, it can be used in ways that keep the carbon stored in biomass and/or that displace the use of fossil fuels (i.e., biomass is combusted off-site for energy capture or used to produce biofuels).[1] If carbon is combusted in a wildfire, the potential bioenergy benefits are lost, as well as the opportunity to produce durable wood products.[2] As shown below, this benefit can be approximated quantitatively.

In addition, studies show that pre-commercial thinning treatments result in an increased rate of growth among remaining trees as a result of reducing inter-tree competition, leading to faster carbon sequestration rates in forests that are treated regularly. This trend may also apply to thinning treatments to reduce fire risk, and could lead to small net gains in forest carbon stocks over time. Due to limited data on the extent of increased growth after fire thinning treatment this GHG benefit was not assessed quantitatively.

Fire mitigation will also reduce the number of future incidences of extreme wildfires. However, the extent to which fires are avoided and the impact on forest carbon stocks of avoided fires is difficult to assess. Fuel thinning treatments can reasonably be assumed to reduce wildfire emissions in the near term and to protect against the loss of large dominant cohort trees. However, because forests are capable of regenerating back to initial carbon densities, over the long term wildfires may not result in net CO_2 emissions or a net loss of forest carbon stocks (i.e., CO_2 emissions from fires are eventually offset by future carbon sequestration on burned sites).[3] There are exceptions, such as when fires permanently alter

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[1] **The GHG reductions associated with the displacement of fossil fuels by the use of biomass feedstocks for energy are quantified under Forestry Options 6 & 7. The feedstock supply assumed under F-6 and F-7 is based in part on the availability of biomass feedstocks from forest thinning treatments under this option.**

[2] The potential for durable wood products to store carbon and to displace the use of more energy-intensive construction materials is addressed in F-4 and F-5.

[3] Kashian, D.M., Romme, W.H., Tinker, D.B., Turner, M.G., and Ryan, M.G (2006). Carbon storage on landscapes with stand-replacing fires. BioScience, Vol. 56 No. 7.

the characteristics of a forest, replacing the original forest with an ecosystem of lower carbon density (e.g., dense forest converted to open grassland or woodland). Uncharacteristically high fuel loads within the forest can create conditions for this type of high-intensity ecosystem altering fire. Consultation with fire experts at DNR suggests that this type of fire is not common in Washington. These complexities have challenged the development of a methodological framework to analyze potential GHG benefits of forest health programs. Advances have been made by researchers at the University of Washington, who developed a lifecycle GHG assessment of long-term impacts of fuel thinning treatments, taking into account carbon in the forest and wood products, and displaced emissions from bioenergy and wood product substitution.[4] Their study finds that when a "no action" baseline is compared to different potential fuel treatment strategies: (1) all treatment scenarios result in more total carbon stored and GHG reductions when the carbon in wood products and avoided emissions from bioenergy and wood product substitution are taken into account; and (2) all treatment scenarios remove more carbon from the forest than wildfires would have, resulting in lower mean carbon in the forest relative to the baseline during the early periods for all treatments and over the long term for most treatments (there are a few treatments with small positive carbon gains after 2020). The study concludes that the measurable carbon benefits of avoided wildfires are found in maintaining the ability of forests to produce wood products and bioenergy, and the net benefits are on the order of a 30% increase in carbon storage and GHG reductions relative to "no action".

Results from the above study were used in conjunction with an assessment of the high-risk forest acres in WA (below) to assess the potential GHG savings from fuel thinning treatments, specifically with regard to maintaining the capacity of forest to produce durable harvested wood products (HWP). The GHG benefits of using biomass from forest thinning treatments to produce bioenergy is encompassed by the analysis of F-6 and F-7 and therefore is not quantified here. HWP substitution effects are not reported separately from bioenery effects in the Lippke et al study; for this reason, and because the HWP substitution effects are likely minimal, they were not assessed below. In addition, it should be noted that this option serves as a potential safeguard of the benefits estimated under F-3 and F-4.

High-Risk Forest Acres

WA Department of Natural Resources (DNR) provided data used to assess the area of high-risk forest. Specifically, DNR provided data on the area of Fire Regime I Forests by Ownership and Condition Class (

[4] Lippke, B., Comnick, J., and Mason, L. (2006). Alternative landscape fuel removal scenarios: impacts of treatment thinning intensity and implementation schedules on fires hazard reduction effectiveness, carbon storage, and economics. RTI/CORRIM Joint Working Paper No. 6.

F Table 1). Fire Regime I forests are the driest forests of eastern Washington. Historically, Fire Regime I forests experience fire events every thirty five years, or less; stands are larger, open grown ponderosa pine with a grass understory; and when they do burn, the fuel consumed in a fire is usually grass and light surface fuels, while large trees are usually undamaged. Fire suppression has allowed these stands to become denser, with a thick understory of pine and Douglas fir. Additionally, most of the largest and most fire resistant trees have been removed. Under current conditions of high fuel loading, fires in Fire Regime I forests are frequently carried to the crowns of trees, killing the all the vegetation. Condition Class is a measure of the departure from the historic fire regime, as determined by the number of missed fire return intervals with respect to the historic fire return interval, and the current structure and composition of the system resulting from alterations to the disturbance regime. Condition Class III represents the farthest departure from historic conditions. Treatment of Condition Class II & III forests with prescribed fire followed by mechanical fuel reduction can move these forests to a Condition Class I status.

F Table 1. Fire Regime I Forests in WA, by Ownership and Condition Class (Acres)

Ownership	**CC I**	**CC II**	**CC III**	**Total**
State	5,000	291,000	45,000	341,000
Tribal	13,000	447,000	108,000	568,000
Federal	22,000	902,000	178,000	1,102,000
Private	30,000	915,000	241,000	1,186,000
Total	70,000	2,555,000	572,000	3,197,000

Using Condition Class II and III forests as a proxy for high-risk areas, the data in

F Table 1. indicate a total of 3,127,000 acres of forest at high risk, of which 1,492,000 acres are in state and private ownership. These data, combined with the goal above (to restore 25% of Washington's "at-risk" state and private forestland to a characteristically healthy state by the year 2020) yields a policy goal to treat a total of 373,000 acres by 2020 (i.e., 28,692 ac/yr starting in 2008).

Under this option, 28,692 ac/yr would be treated with some combination of prescribed burning and mechanical fuel removal to offset the risk of future wildfire. It is assumed that this treatment will prevent the eventual burning of these acres in future wildfires.

Suitability for treatment could not be factored into the analysis of available acreage due to limited time and resources; however a multi-criteria analysis of forest suitability for potential fuel reductions has been completed for WA, taking into account distance from roads, distance from power plants, and slope.[5] The analysis maps a suitability index for WA forests that could be superimposed on the acreages provided by DNR above to identify those areas most suitable for treatment.

GHG Benefits of Maintaining HWP Production Capacity through Avoided Fires

A coefficient for the additional amount of carbon stored in HWP as a result of fuel thinning treatments and avoided fires was derived from the findings of Lippke et al (2006). The study modeled the impacts of phased-in forest thinning over 25-yrs starting in 2000[6] on forest carbon and HWP carbon, and GHG savings associated with substitution of HWP for other building materials and of biomass to produce energy. Three different treatment regimes were modeled and are described below.

- **12 & Over:** Removing trees 12 inches in diameter at breast height (DBH) and larger (12&Over), represents a selective harvest of the largest and most valuable trees. This treatment demonstrates a high short-term revenue yield that maximizes production of long-lived products. This treatment is reminiscent of past practices sometimes referred to as high grading.
- **9 & Under:** Removing trees 9 inches DBH and lower (9&Under) demonstrates a light touch attempt at lowering the fire intensity hazard while retaining as much large tree biomass in the forest as possible. With this treatment little merchantable material is removed. This treatment was proposed for broad application on Inland West National Forests by Babbitt and Glickman in 2000.
- **BA45:** Thinning from below to a target of 45sq. ft. basal area per acre (BA45) represents an opportunity to generate revenue while leaving the largest trees, reducing the ladder fuels that are known to increase the fire hazard, and returning the forest to more open pre- settlement

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[5] May 2007. Carbon Sequestration through Changes in Land Use in Washington: Costs and Opportunities. Winrock International, Arlington, Virginia.

[6] The study also modeled the impacts of immediately thinning 586,323 acres in 2000, followed by no continued annual treatment. Results from the phased-in treatment plan were used in this analysis because the approach is more consistent with the policy outlined here.

conditions. For reference, 45 sq. ft. of basal area per acre is approximately equivalent to 57 trees per acre that are 12 inch DBH.

Model results of the carbon stored in HWP by treatment group, and the number acres treated annually, were used to derive a HWP carbon savings coefficient (F Table 2). The model shows net gains in HWP carbon in all treatment groups compared to the "no action" (or baseline) case where zero additional HWP carbon is stored. The magnitude and timing of the impacts vary by treatment group, as does the number of acres treated each year. The average annual HWP impact and acres treated during 2000-2020 were calculated and used to derive the average annual per acre HWP impact by treatment group. Then a single average across all treatment groups was calculated. This approach implies that all three treatments are equally likely to occur under implementation of the F-1 policy option. The final coefficient is converted to standard units of million metric tons of CO_2 equivalent.

F Table 2. Model Results and Calculated HWP Carbon Savings from Fuel Thinning Treatments.

Year	HWP Impacts (MMtC/yr)			
	No Action	12&Over Phased in	9&Under Phased in	BA45 Phased in
2000	0	1.4	0.4	1
2005	0	2.5	0.6	1.9
2010	0	3.4	0.8	2.7
2015	0	4.1	1	3.4
2020	0	4.7	1.1	4
Average annual HWP impact	0	3.2	0.8	2.6
	Acres Treated (acres/yr)			
	No Action	12&Over Phased in	9&Under Phased in	BA45 Phased in
2000	0	117,265	117,265	117,265
2005	0	99,660	103,430	105,594
2010	0	85,714	89,051	95,221
2015	0	73,681	78,120	86,887
2020	0	62,820	67,259	75,845
Average annual acres treated	0	87,828	91,025	96,162
	No Action	12&Over Phased in	9&Under Phased in	BA45 Phased in
Average annual per acre impact for each treatment group	0	0.00004	0.00001	0.00003
Average annual per acre impact across all treatments	0	0.00002		
Average annual per acre impact across all treatments ($MMtCO_2e$/yr/acre)	0	0.00009		

The Lippke study provides limited details on the specific derivation of the HWP carbon benefits. Based on an initial review, it appears as though the values in F Table 2 are the immediate volumes of carbon transferred to HWP after harvesting and do not take into account the long-term dynamics of HWP carbon fluxes, i.e., future emissions of carbon from HWP as a result of decomposition, combustion, and disposal. These temporal dynamics make it difficult to assess the permanent amount of carbon stored in HWP and thus the lasting GHG benefits. As discussed in the analysis of F-3 and F-4, a standard accounting method has been developed to address this temporal issue. Using the so called "100-yr method", the F-3/F-4 analysis finds that about 21% of carbon initially transferred to HWP after harvest remains stored 100-yrs later in western WA state. This fraction was applied to the HWP carbon savings estimated in F Table 2 to account for long-term carbon losses, yielding a final carbon savings coefficient of 0.00002 $MMtCO_2e$/yr/acre treated.

Under this option, 28,692 ac/yr would be treated each year from 2008-2020. This value, multiplied by 0.00002 $MMtCO_2e$/yr/acre treated yields an annual estimated carbon savings of 0.5 $MMtCO_2e$. The sum of annual benefits from 2008-2020 yields cumulative carbon savings of 7 $MMtCO_2e$.

Cost Analysis

There are at least four potential types of costs and cost savings related to this option: cost of treatments, cost of transporting biomass to energy consumers, cost savings from revenue generated by the sale of biomass for energy, and cost savings from the avoided costs of catastrophic fires. The costs calculated here focus on those most proximal to forest treatment and associated impacts of reduced fire risk. The costs and cost savings associated with transporting and selling biomass for energy production are accounted for in F-6 and F-7.

The cost of forest thinning was based on the typical cost of pre-commercial thinning as reported by the Forest Stewardship Program (cost-share rates), at $220/acre. Costs associated with prescribed fires were also based on estimated cost-sharing rates of roughly $150/ac. Assuming both treatments will be used on all acres, total treatment costs are $370/acre. Cost savings from avoided fires is estimated to be about $1,700 per acre not burned, based on an assessment of the costs of fire fighting, rehabilitation, indirect economic losses, and long-term rehabilitation after a catastrophic wildfire in Hayman, Colorado at the wildland urban interface (Front Range Partnership Report 2006). This value is consistent with the expert opinion of DNR, which placed the avoided costs from preventing fires between $1,000-$2,000 per acre.

Costs were calculated annually by multiplying the number of acres treated each year by $370/acre (yielding $10.6 million). Cost savings were also calculated annually, by multiplying the number of acres treated by $1,700 (yielding $48.8 million). Annual net costs were calculated by subtracting annual costs savings from costs, yielding cost savings of $38 million per year. Annual costs were discounted over the time period analyzed (2008-2020) using a 5% discount rate. The sum of annual discounted costs from 2008-2020 gives an assessment of the net present value (NPV) of this option, on the order of -$376 million, where the negative value indicates cost savings. The cost effectiveness of this option (NPV divided by cumulative GHG savings) is -$54/ton CO_2e.

Additional Data Resource

www.dnr.wa.gov/htdocs/rp/forhealth.html

Forest Health Strategy Work Group reports in 2004 and 2006. "A Desirable Forest Health Program for Washington's Forests". December, 2004
http://www.dnr.wa.gov/htdocs/rp/forhealth/fhswgc/pdf/foresthealthreport.pdf

"Forest Health Strategy Work Group Report to the Legislature". December, 2006
http://www.dnr.wa.gov/htdocs/rp/forhealth/fhswgc/fhrepttolegdec06.pdf

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): This option includes goals to restore all 1.5 million acres of "at risk" state and private forest lands to a characteristically healthy state by 2050, and to maintain forest in that condition thereafter by periodic fuel treatments. To the extent that uncharacteristically severe wildfire would otherwise occur on untreated lands during this time period and regrowth following fires would not achieve pre-fire levels of carbon storage in this period, fuel reduction treatments could continue to provide net carbon benefits by making material removed from the forest available to the energy and forest products markets, substituting for more carbon intensive fuels and products.

Job Creation: Fuel reduction treatments, particularly mechanical treatments, can be labor intensive, and therefore a source of new jobs, especially in rural areas.

Reduced Fuel Import Expenditures: A direct goal of this option is to provide in-state biomass feedstock, from fuel treatments in un-healthy forests, to supply energy facilities, thereby displacing fossil fuel sources at such facilities, or to be converted into fuel.

Key Uncertainties

The quantitative analysis of carbon benefits should be considered preliminary as it is based on a single, non-peer reviewed study and the GHG reduction estimates were not reviewed by the full TWG due to time constraints.

The biomass feedstock supply estimate from F-1 is highly sensitive to assumptions about the acres treated, the amount of biomass available and the amount removed. Market demand will influence how much of the biomass removed is used to produce bioenergy or biofuels.

Additional Benefits and Costs

Protection of residential and or municipal lands from fire risk

Healthier forests

Protection of watersheds, wildlife and wildlife habitat, and improvements in air quality (e.g., lower air emissions occur from energy utilization compared to open burning)

Potential expansion of markets for industrial producers of renewable energy use

Creation of jobs in the associated forestry management industries

Forest fire mitigation is a potentially important strategy for adapting to future climate change

Feasibility Issues

Diversity of landowner objectives will influence the potential for full implementation of treatments on the number of acres targeted by this option.

Site specific treatment designs still need to be developed, Physical limitations to treatment e.g., accessibility to sites and slope at sites (35% or less is preferred). See above for discussion of available data on site suitability).

Economic viability, either through public spending, infrastructure or markets, is uncertain.

Policy challenges include involving Federal Lands, establishing baselines and demonstrating additionality.

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-2 Reduced Conversion to Nonforest Cover

Mitigation Option Description

Reduce conversion of forest lands to non-forest cover and to reduce the rate at which forested tracts are parceled and/or fragmented. The conversion of forestlands to other uses is a direct cause of carbon emissions due to the loss of biomass and soil disturbance. Non-forested areas contain lower amounts of biomass and associated carbon reserves. These areas also have less capacity to sequester carbon dioxide than forested areas.

Implicit within this mitigation option is the recognition that 1) forests, depending on how they are managed, may be a net source or a net reservoir of CO_2 and 2) a continuous loss of forestland regardless of the rate will ultimately lead to the loss of scale for the forest industry, wild life and WA private forests to make any significant contribution to carbon sequestration. This proposed option will promote the development of incentive programs that maintain forestland by reducing conversion and promoting forests' ability to continue to sequester carbon. This proposed option additionally aims to position Washington State forestland owners to participate in emerging carbon trading markets. This policy will include an analysis of population growth and its impact on forest land conversion and how incentives can minimize its impacts until an elimination of conversion is achieved. If these voluntary programs selected are not attaining the desired resolute, then it will be the responsibility of the state to increase or enhance the incentives so that landowners are providing the desired sequestration service.

Mitigation Option Design

Goals: Reduce the acres of forestland expected to be lost to non-forest uses by 70% by 2020.

Timing: Policy initiation: by 2010 reduce expected loss by 10%, by 2020 reduce the expected loss by 70%.

Coverage of parties: Private Forest Land Owners (particularly Small Forest Landowners on the urban fringe); Regional and Local Land Trusts; Western Climate Initiative; NGO's throughout the state; WSU Forestry Dept.; Washington State DNR; Washington Department of Ecology and EPA; Washington State and Local Legislatures.

Other: It will take some time to develop and implement market initiatives and incentives programs that can stem the rate of conversion to non-forest use and for those reasons the 2010 goal is modest. But it is expected that with the full implementation of many of the mechanisms listed below dramatic decreases in the rate of conversion will be achieved. If these voluntary mechanisms are affective we hope to see an increase in forested land after 2030.

Since the 1930's, Washington State has lost 2 million acres of timberland to other uses. But the trend has accelerated: over the next several years, 300,000 acres of Western Washington timberland is likely to be converted to other uses (Alig et al, 2003)[7].

Two demographic surveys conducted by Washington State University (WSU) and the Washington Farm Forestry Association also revealed that the average age of small forest landowners is between 57 – 67 years old. These figures imply that a large percentage of this land base will change hands within a generation, likely leading to increased fragmentation and conversion.

Implementation Mechanisms:

WA to fund and perform a study on current rates of private forest land conversion to other uses, including data on geography and demographics of landowners. These numbers will help to prioritize conservation efforts by the state and others in order to achieve the goals of this mitigation option.

The state to provide more analysis to help identify rates of conversion on a county by county level and credit the amount of carbon associated with maintaining the forest land cover as a percentage of the rate of conversion in the area (see CA Forest Protocols as reference).

WA to participate in the development of a regional regulatory Cap and Trade system that recognizes forestry projects that could provide carbon sequestration offsets, including avoided deforestation of forestland. Liability for changes in carbon stocks on the land should be clearly established, tracked, and managed over time following GHG accounting and registry requirements for transparency. Contracts that engage traditional risk management methods can be used to ensure the replacement and/or funds to acquire replacement of any "non-permanent" forest-based credit. GHG contracts should assign liabilities for loss, loss mitigation, and counter-party obligations to disclose and register changes in registered carbon stocks.

Make environmental mitigation more efficient for developers and effective for conservation to reduce negative environmental impacts of development.

Accelerate the development of conservation markets in order to create new income streams to landowners for conservation actions.

Encourage conservation easements used to maintain working forestland that are threatened with conversion

Expand the use of transfer of development rights (TDR) in areas facing rapid development through regional markets, incentives to receiving areas for increased density, and capacity building for financially constrained local governments (this mechanism linked with Transportation option 4 and Residential, Commercial and Industrial option 3.)

Implementation of the Conservation Villages concept will provide an alternative to large lot development. Each Conservation Village, a receiving site for development right transfers, will

[7] Alig, R. J., A. J. Planting, S. Ahn, and J. Kline. 2003. *Land use changes involving forestry in the United States: 1952 to 1997, with projections to 2050.* U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: Portland, Oregon.

permanently protect working forests by transferring currently allowed development potential to compact, green-build developments.

Working Lands Revolving Loan Fund will provide government entities access to low or no-interest loans for transactions that permanently keep land in economically active forestry through TDR. Local bodies then resell to private market, having removed real estate development value. Greater affordability of working forests will help transfer Washington's resource legacy to the next generation.

New tax incentives that encourage forest management for greater forest sequestration and avoid conversion, including the development of an Anti-Forest Conversion designation that works similarly to open space designations for agriculture. This designation would allow forest landowners to avoid paying specific state taxes as long as the forest lands remained as working forests. At the point of conversion, past taxes would have to be re-paid.

Washington will undergo a study to determine inadvertent regulatory or tax disincentives to forestry, including inheritance taxes laid on next generation foresters.

Add consideration of climate impacts criteria to existing project environmental review requirements (e.g. SEPA requirements for projects that convert forests to non-forest uses). This is not intended to extend SEPA coverage to currently exempt forest practices. See also RCI-9.

Educate Washington citizens on the importance of working lands and the quality environmental stewardship performed by our landowners in order to increase the value of forest lands to the public beyond their value as real estate. Note: This mechanism does not have direct emissions benefits. It should possibly be moved to another section.

Related Policies/Programs in Place

Examples of Direct Payment Incentive Programs

Program	Program Implementer	Type of Action	Benefits	Acres protected	Program support
Forest Legacy Program	U.S. Forest Service & WA DNR	**Grant program** funds up to 75% of project costs, typically a conservation easement.	Private landowner	~15,000	$6.2 million
Conservation Reserve Enhancement Program	Farm Services Agency & Washington State Conservation Commission	**Cost share** covers up 50% of the eligible costs to reforest riparian areas.	Private landowner	8,100	$1.3 million
Conservation Innovation Grants Program	Natural Resource Conservation Service (NRCS)	**Cost share** transfers conservation technologies, management systems, and innovative approaches (i.e. market-based systems).	Organizations or academic institutions		
Healthy Forests Reserve Program	NRCS	**Cost share** funds 50-100% of the costs of voluntary easement program established to restore/enhance forest ecosystems & promote recovery of threatened and endangered species, enhance carbon sequestration.	Private landowner		Not in WA; was a pilot program in FY 06 in Arkansas, Maine, and Mississippi
Landowner Incentive Program	WA Department of Fish and Wildlife (WDFW)	**Grant program** supplements the protection & restoration of federally listed, proposed or candidate species on private lands.	Private landowner		Up to $50,000 for individual landowners
Wildlife Habitat Incentives Program	NRCS	**Cost share** provides technical and financial assistance to landowners to restore native vegetation and habitat for threatened and endangered species.	Private landowner		
Forestry Riparian Easement Program	WA DNR - Small Forest Landowner Office (SFLO)	**Grant program** compensates eligible small forest landowners in exchange for a 50-year easement on "qualifying timber" within riparian areas.	Private landowner	1,813	$5.2 million
Family Forest Fish Passage Program	WA DNR - SFLO, WDFW, Salmon Recovery Funding Board	**Cost share** provides 75-100% of the cost of correcting a barrier; also provides technical assistance.		236 miles of stream opened	$4.3 million
Forest Land Enhancement Program	U.S. Forest Service & Washington DNR	**Cost share** provides for technical, educational, and cost-share assistance to promote sustainability of non-industrial private forests.	Private landowners (small)		
Riparian Open Space Program	WA DNR	**Grant program** qualifying landowners can donate or sell their land and/or timber in designated forest land that exists along migrating stream channels. There are also options to sell the state permanent conservation easements covering the timber and/or forest land provide.	Private landowners	584	$1.47 million
Conservation Easements	Land conservation organizations, state agencies, counties	**Direct payment** voluntary legal agreement that restricts the development and future use of a piece of property, transfers those rights to qualified conservation organization or agency.	Private landowners		
Transfer Development Rights	King County, in development elsewhere in the state	**Direct payment** trading of zoning privileges from areas with low population needs, such as forest land, to areas of high development needs, such as urban core areas. Typically includes a conservation easement on sending site.	Private landowners	92,000	$22 million in value
Acres protected and program support are best available estimates as of 2006 and are not complete for all programs.					

Source: Bradley, G, A. Erickson, A. Robbins, G. Smith, L. Malone, L. Rogers, and M. Connor. 2007. Future of Washington's Forest and Forest Industries Study. Final Report 2007. Study 4: Land Conservation. http://www.ruraltech.org/projects/fwaf/final_report/pdfs/05_Study4_LandConv.pdf

Types(s) of GHG Reductions

Avoided CO_2 emissions from carbon stock losses that occur when forests are converted to other uses

Maintenance of annual carbon sequestration potential in forests that are not converted to development

Maintenance of carbon sequestration potential in harvested wood products (not quantified)

Estimated GHG Savings (in 2020) and Costs per $MtCO_2e$

			Reductions	($MMtCO_2e$)*			
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) $ millions**	**Cost-Effective-ness $/$tCO_2$**
F-2	Reduced conversion to non-forest cover	Reduce rate of conversion by 70% by 2020	1.1	4.7	26.8	$556*	$22.42*

* Based on analysis of Westside only

Data Sources: Data on rates of forest conversion to development from NRCS National Resource Inventory and The Future of Washington's Forests and Forestry Industries Study 4: Forest Land Conversion in Washington State; forest carbon densities from the CCS Inventory and Forecast Appendix H on Forestry; forest sequestration rates calculated from PNW defaults in the US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US, General Technical Report NE-343 (also published as part of the Department of Energy Voluntary GHG Reporting Program); data on distribution of forest types in eastern and western WA from USFS Forest Inventory Analysis; Assumptions about carbon losses from (a) Strong, T.F., 1997 "Harvesting Intensity Influences the Carbon Distribution in a Northern Hardwood Ecosystem," USFS Research Paper NC-329 and (b) "The Intersection of Land Use History and Exurban Development: Implications for Carbon Storage in the Northeast" Undergraduate Thesis, K. Austin, 2006); cost data are derived from the Multiple Listing Service and from The Future of Washington's Forests and Forest Industry Study 1: Timber Supply and Forest Structure
http://www.ruraltech.org/projects/fwaf/final_report/index.asp#toc

Quantification Methods:

GHG Benefits

This option maintains a certain percentage of forest land that would otherwise be converted to developed land, assuming current rates of forest conversion continue out into the future. The carbon savings are estimated from two sources: the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., "avoided emissions"); and the amount of annual carbon sequestration in the forest area that is not converted to development under this option (i.e., "protection of carbon sequestration potential"). Data are available to allow for separate estimates for the East- and Westside of WA, which allows the analysis to take into account different underlying forest conversion trends, predominant forest species, and carbon densities between these regions.

Baseline future rates of forest conversion (in State and private ownership) were calculated from land use change data reported by the Natural Resources Inventory (NRI) and from data reported by the University of Washington, in The Future of Washington's Forests and Forest Industry Final Report (study 4). NRI is one of the few available sources of land use data that provides information on specific land use changes by US state. NRI data are for Non-Federal lands (although the amount of Non-Federal land moving into Federal ownership is also tracked). In addition, NRI provided CCS with separate West- and Eastside estimates for WA. The 1992-1997 time period is the most recent for which NRI data are available for specific land use conversions (i.e., from forests to urban land uses). The UW analysis incorporates recent trends (1988-2004), and covers roughly the same forestland base as NRI (non-federal lands).

NRI data are shown in F Table 3 and F Table 4 below. The annual average rate of forest conversion to development is calculated as the number of forest acres converted to urban land uses from 1992-1997 divided by 5 years. This value divided by the initial forest area in 1992 yields the percent change per year. Based on NRI, estimated annual average rates of forest conversion to development for Western WA are 19,500 acres/yr, or 0.25%/yr, and for Eastern WA are 3,560 acres/yr, or 0.07%/yr.

F Table 3. Trends in Forest Conversion, Westside of WA, 1982-1997

	1982-1987	**1987-1992**	**1992-1997**
Initial Non-Federal Forest Acres	7,995,000	7,931,700	7,789,800
Final Non-Federal Forest Acres	7,904,200	7,780,800	7,663,300
Change	90,800	150,900	126,500
Non-Federal Forests Converted to:			
Cropland	0	1,200	0
Conservation Reserve Program	0	0	0
Pastureland	2,400	17,600	17,100
Rangeland	0	0	0
Minor land cover/uses	4,300	6,400	8,400
Urban land use	**43,500**	**124,800**	**97,500**
Water	1,300	900	2,300
Federal land	39,300	0	1,200

F Table 4. Trends in Forest Conversion, Eastside of WA, 1982-1997

	1982-1987	**1987-1992**	**1992-1997**
Initial Non-Federal Forest Acres	5,102,300	5,093,600	5,134,600
Final Non-Federal Forest Acres	5,079,900	5,082,000	5,098,300
Change	22,400	11,600	36,300
Non-Federal Forests Converted to:			
Cropland	2,200	0	0
Conservation Reserve Program	0	0	0
Pastureland	0	1,000	0
Rangeland	9,100	2,900	15,000
Minor land cover/uses	100	900	3,300
Urban land use	**2,100**	**5,600**	**17,800**
Water	200	100	200
Federal land	8,700	1,100	0

The UW study employed land cover classification over several time periods to analyze rates of land conversion on the Westside. The analysis found that 5% of forestland was converted to urban and developed uses during 1988-2004. This is equivalent to an average annual conversion rate of 0.31%/yr. This rate is slightly higher than the rate calculated from NRI and is more likely to include recent trends in forest conversion. Therefore, the baseline rate of forest conversion for Western WA used in the analysis below is based on the more recent UW data. The UW study does not provide a value for the area of forest land in 1988. NRI data on forest area in 1987 were combined with the 0.31%/yr rate from the UW study to calculate a forest conversion rate in terms of acres per year (7,931,700 acres * 0.31%/yr = 24,787 acres/yr). The UW study also provides data on timberland conversion to urban uses by ownership classes. These data suggest that the majority of timberland conversion occurs on private non-industrial forests (i.e., ~84%). As indicated above, a key Implementation Mechanism will be a more detailed analysis of GHG benefits including factors like geography and land ownership characteristics.

At the goal levels specified by this option, the baseline rates of forest conversion to development would be reduced by 10% by 2010 and 70% by 2020. This amounts to the avoided conversion of 2,479 acres/yr by 2010 and 17,351 acres/yr by 2020 on the Westside, and 356 acres/yr by 2010 and 2,492 acres/yr by 2020 on the Eastside.

Loss of forests to developed uses typically results in the near complete removal of forest trees as well as significant soil disturbance, causing a substantial one-time loss of carbon stocks stored in forest biomass and soils. For this analysis, it was assumed that 53% of carbon stocks in biomass and 35% of carbon stocks in soils would be lost in the event of forest conversion, with no appreciable carbon sequestration in soils or biomass following development. The biomass loss assumption is based on research that shows heavy levels of individual tree removal results in the harvesting of 53% of carbon in aboveground biomass (Strong 1997). The soil carbon loss assumption was based on a study that shows about a 35% loss of soil carbon when woodlots are converted to developed uses (Austin, 2006).

Average forest carbon stocks (tons carbon per acre) are multiplied by the anticipated percentage loss of carbon due to development to yield avoided emissions coefficients. Average forest carbon stocks are provided in the WA Inventory and Forecast report Appendix H, which is the source for the biomass and soil carbon stocks used in this analysis and shown in F Table 5 below. To estimate avoided emissions, the avoided emissions coefficients for biomass and soils are multiplied by the acres of forests that avoid conversion each year.

F Table 5. Avoided emissions coefficients (tons C/ac).

	Westside		**Eastside**	
	Avg. Carbon Stock	Avoided Emissions Coefficient	Avg. Carbon Stock	Avoided Emissions Coefficient
Biomass	81.58	43.24	47.11	24.97
Soils	40.72	14.25	29.26	10.24

Forests that are protected from conversion in one year continue to sequester carbon in subsequent years, which is carbon sequestration that would not have occurred if the forest were converted to development. This is estimated and included as an additional GHG benefit using average annual carbon sequestration rates for Western and Eastern WA, calculated from published carbon yield tables (USFS GTR NE-343). These data were combined with FIA data on acres by forest type and region of WA to calculate an area-weighted average carbon sequestration rate for Eastern and Western WA (F Table 6). Annual sequestration rates were based on a 65-yr average and calculated by subtracting biomass carbon stocks in 65 yr old stands from biomass carbon stocks in new stands and dividing by 65. Sixty-five years was chosen to approximate the average stand age distribution in WA. Soil carbon stocks are constant across stand age in the published yield tables, therefore, sequestration in soils is assumed to be zero in the analysis.

Annual sequestration is calculated by multiplying the cumulative forest acres that avoided development each year by the appropriate average carbon sequestration rate. Cumulative acres are used because forests that are protected from conversion in one year continue to sequester carbon in subsequent years.

F Table 6. Weighted average annual carbon sequestration rates for WA

Region	Forest Type	Area (acres)	Biomass Stocks (tons C/ac) for new stands (0 yrs)	Biomass Stocks (tons C/ac) for 65 yrs old stands	Sequestration (tons C/ac/yr)
Eastside	Douglas-fir	3,564,564	27.4	86.4	0.91
	Fir-spruce-mountain hemlock	1,575,167	23.7	58.6	0.54
	Lodgepole pine	622,528	17	45.3	0.44
	Ponderosa pine	2,101,228	15.6	34.9	0.30
	Area-weighted average				**0.63**
Westside	Alder-maple	1,847,329	18.7	138.8	1.85
	Douglas-fir	4,920,078	33.3	183.9	2.32
	Fir-spruce-mountain hemlock	1,795,660	23.5	114.2	1.40
	Hemlock-sitka spruce	3,074,643	30.5	116.1	1.32
	Area-weighted average				**1.84**

All estimates are converted from tons carbon to million metric tons of CO_2 equivalent ($MMTCO_2e$). Result for both avoided emissions and protected sequestration capacity are shown in

F Table 7 and

F Table 8.

F Table 7. GHG Benefits of Avoided Forest Conversion to Development in Western WA

	Forest Acres Avoiding Conversion	Total Avoided Emissions (tons C)	Protected Sequestration Capacity (tons C)	Total ($MMtCO_2e$)
2008	826	47,501	1,517	0.18
2009	1,652	95,002	4,551	0.37
2010	2,479	142,503	9,102	0.56
2011	2,974	171,004	14,563	0.68
2012	4,462	256,506	22,755	1.02
2013	5,949	342,008	33,678	1.38
2014	7,436	427,510	47,331	1.74
2015	8,923	513,012	63,714	2.11
2016	10,411	598,514	82,829	2.50
2017	11,898	684,016	104,674	2.89
2018	13,385	769,518	129,249	3.30
2019	14,872	855,020	156,555	3.71
2020	17,351	997,523	188,412	4.35
Total	102,618	5,899,638	7,362,193	24.78

F Table 8. GHG Benefits of Avoided Forest Conversion to Development in Eastern WA

	Forest Acres Avoiding Conversion	Total Avoided Emissions (tons C)	Protected Sequestration Capacity (tons C)	Total ($MMtCO_2e$)
2008	119	4,178	75	0.02
2009	237	8,356	225	0.03
2010	356	12,535	451	0.05
2011	427	15,042	721	0.06
2012	641	22,562	1,126	0.09
2013	854	30,083	1,667	0.12
2014	1,068	37,604	2,343	0.15
2015	1,282	45,125	3,154	0.18
2016	1,495	52,645	4,100	0.21
2017	1,709	60,166	5,182	0.24
2018	1,922	67,687	6,398	0.27
2019	2,136	75,208	7,750	0.30
2020	2,492	87,742	9,327	0.36
Total	14,738	518,934	669,862	2.06

Cost Analysis

Cost data were available for Western WA only. Therefore the cost analysis is limited to this region. The GHG benefits are largely attributed to Western WA due to the relatively large baseline rate of forest conversion in the Western region. Thus, the analysis is believed to be a good representation of the overall costs.

Both costs and cost savings are taken into account in this analysis. Costs are approximated as the market price of forest land, which is assumed to reflect the minimum amount of compensation needed to prevent a decision to sell to developers. An average market price of $12,381/acre was calculated from the forest land sale prices (for parcels >10 acres) in Western WA as listed in the MLS database. The specific mechanism for compensating land owners is not prescribed here as there are several potential vehicles (e.g., conservation easements, carbon offsets markets, etc.)

The net loss of working forest land in WA has implications in terms of lost forest revenue from multiple revenue streams, including for example state taxes. Researchers at the University of Washington have estimated the net economic impact of preventing forest conversion by comparing the present value of forest revenues under two future scenarios, one with and one without forest conversion to other uses (see tables 1.16 and 1.17 in the Future of Washington's Forests and Forest Industry: Study 1). The report shows net economic benefits to eliminating conversion of industrial forests to other non-forest uses and projects that both the total and per acre present value of industrial forests goes up when forest conversion ceases. The study estimates that the present value of industrial forests increases by about $1.169 million overall if conversion of 272,000 acres of industrial forests is prevented. These statistics were used to calculate a potential cost savings based on the forest revenues saved per acre of forest that is not converted of $4,298/acre ($1.169 million in savings divided by 272,000 acres not converted yields $4,298 per acre not converted).

Costs minus cost savings yield a net cost per acres of $8,083 per acre not converted (i.e., $12,381 minus $4,298). Net costs per acre are multiplied by the forest acres that avoid conversion each year to yield annual costs. Annual discounted costs are then estimated using a 5% interest rate. The sum of annual discounted costs provides an estimate of the Net Present Value (NPV) of this option, which amounts to $437 million. The cumulative cost effectiveness of the total program was calculated by dividing the NPV by cumulative carbon benefits of this option for Western WA, yielding $22/ton CO_2e.

F Table 9. Summary of Cost Calculation, for Western WA only

	Acres Protected	Carbon Savings ($MMtCO_2e$)	Cost	Discounted costs
2008	826	0.18	$6,678,614	$6,678,614
2009	1,652	0.37	$13,357,228	$12,721,170
2010	2,479	0.56	$20,035,842	$18,173,100
2011	2,974	0.68	$24,043,011	$20,769,257
2012	4,462	1.02	$36,064,516	$29,670,367
2013	5,949	1.38	$48,086,022	$37,676,656
2014	7,436	1.74	$60,107,527	$44,853,162
2015	8,923	2.11	$72,129,033	$51,260,757
2016	10,411	2.50	$84,150,538	$56,956,397
2017	11,898	2.89	$96,172,044	$61,993,357
2018	13,385	3.30	$108,193,549	$66,421,454
2019	14,872	3.71	$120,215,055	$70,287,253
2020	17,351	4.35	$140,250,897	$78,096,947

Total	102,618	24.78		$555,558,490

Key Assumptions:

Baseline rate of forest conversion to developed uses for Westside is assumed to be 24,787/yr, or 0.31%/yr (NRI 1997 forest area and UW Study 4, non-federal land)
Baseline rate of forest conversion to developed uses for Eastside is assumed to be 3,560/yr, or 0.07%/yr (NRI 1992-1997, non-federal land)

53% of biomass carbon stocks are lost/emitted during conversion (Strong 1997)

35% of soil carbon stocks are lost/emitted during conversion (Austin 2006)

Net costs are estimated at $8,083/acre, using land value to approximate costs of $12,381/acre and potential lost forest revenues to approximate cost savings of $4,298/acre

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): To the extent that the forest lands that avoid conversion during 2008-2020 remain in forest land use, they will continue to sequester carbon annually. In addition, if the rate of forest conversion continues to decrease during 2035-2050, additional significant GHG benefits can be realized.

Job Creation: Currently 48,000 jobs in Washington State are forest industry related http://www.nwenvironmentalforum.org/ForestForum/topicpapers/tp4.pdf. With the loss of forest land in the state, jobs in the forest industry also are lost. Most of the conversion of forested lands to non forest use are related to the loss of small forest land holdings which contribute a significant portion of the timber that supports the remaining mills in Washington State (Non-industrial private forest harvests account for nearly 30% of timber harvested in the state, making up 3.1 million acres of forests).

Reduced Fuel Import Expenditures: Contributions to fuel reduction will occur where reduced forest conversion occurs in conjunction with reduction of urban sprawl into rural areas. With reduced conversion rates development may be concentrated into cities towns reducing commute times for shopping and to places of work.

Key Uncertainties

Analysis of this option is sensitive to assumptions about the future rate of forest conversion. The rates assumed in this analysis are based on recent historic trends. Actual baseline rates may be greater due to development trends. One study using empirical modeling to describe probable future land use trends in western Washington out to 2050 found that over a 53 yr time period, approximately 1% of forests would be converted to developed uses (i.e., 0.02%/yr) and that most of the conversion would take place on non-industrial privately owned timberland [8].

The actual amount of carbon stocks in soils and biomass that is lost during conversion will vary by site characteristics, intensity of forest clearing, and development methods.

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[8] Kline and Alig, 2001. A spatial model of land use change for western Oregon and western WA, USFS PNW RP-528.

Forest conversion to agriculture or rights-of-way is not taken into account in the analysis; inclusion of this type of forest loss would increase the estimated GHG impacts.

Additional Benefits and Costs

This option also protects the potential for working forests to produce harvested wood products, which store carbon for long periods of time. This is not accounted for in the quantification above, but if it were taken into account, it would increase the estimated GHG benefits.

In addition, this option would:

- Support intact rural communities in traditional land uses;
- Maintain land for recreational opportunity, critical wildlife habitat, productive timberland, and water quality;
- Have the potential to enhance smart-growth objectives (to be expanded, including reference to T-2).

Feasibility Issues

None cited

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-3 Enhanced Carbon Sequestration in Forests

Mitigation Option Description

Washington forests have a significant role to play in decreasing net emissions of carbon dioxide (CO_2) by removing CO_2 from the atmosphere. Our forests are among the most productive in the world, and programs designed to encourage management of our forests for increased overall forest carbon stocks can be an important part of the state's climate action strategy. Special programmatic emphasis should be placed on opportunities to increase and maintain overall carbon storage in the most stable reservoirs in the forest environment, especially stems, roots, and soils.

This mitigation option is designed to promote the removal of additional CO_2 from the atmosphere by increasing and maintaining overall carbon stocks in Washington forests relative to an established baseline. The baseline should not be established solely on the basis of the estimated amount of carbon sequestered in Washington forests at a single point in time. The baseline should also take into account projected trends in sequestered forest carbon levels, particularly as those levels are expected to be affected by factors such as current regulatory requirements and forest management practices and by projected forest losses from fire resulting from unnatural fuel loading.

Net storage of forest carbon is influenced by many factors, including the conversion of forests to non-forest uses, forest health, and the wood products manufacturing process. These and other important issues related to enhanced carbon sequestration in Washington forests are addressed in other forestry mitigation options (e.g. F-1 addresses forest health, F-2 addresses forest conversion and F-4 addresses wood product carbon storage). In addition to other important policy goals (e.g. preservation of natural habitat and species biodiversity), this mitigation option includes as a policy goal the preservation of our state's public and private working forests. In support of these goals, this option aims to position our state's public and private working forest landowners to participate meaningfully in emerging carbon trading markets.

Mitigation Option Design

Goals: Help position Washington forest landowners to participate meaningfully in emerging carbon offset markets by implementing voluntary programs and incentives which, together with emerging market opportunities, will increase absolute levels of sequestered carbon relative to an established baseline in Washington forests (exclusive of Federal and Tribal forestlands).

Update and improve the WA Inventory and Forecast for Forestry periodically to enable establishment of baseline net forest carbon stocks, starting in 2008.

Participate in the development of accounting protocols (e.g., via The Climate Registry) to measure changes in forest carbon stocks, by the end of 2009.

Adopt legislation, rules, or other measures as necessary to implement voluntary programs and incentives for achieving increases in net forest carbon stocks, consistent with maintaining or enhancing healthy native forests that support environmental values by 2011.

Implement afforestation to restore available land to historic forest conditions (not quantified)[9] and encourage planting trees in available city and urban space (covered under F-8).

Implement forest management to improve productivity on 50% of available forest acres by 2020 (quantified below).

Coverage of parties: Washington Governor; Washington Legislature; Executive Departments (e.g. Ecology, DNR, CTED; OFM; Revenue); Climate Action Challenge stakeholders; large and small forest landowners; foresters and climate scientists; and general public.

Other: none cited

Implementation Mechanisms:

The design for this mitigation option includes WA state participating in development of greenhouse gas accounting protocols for the forest sector to quantify and verify real, additional and durable emission reductions that provide emissions reductions exceeding those anticipated under the established baseline. The accounting protocols used to quantify emissions reductions should 1) quantify annual increases and decreases in forest carbon stocks above the baseline (live and dead carbon pools, including wood product carbon), 2) secure/account for the protection (i.e. "permanence") of overall carbon stocks and 3) quantify and verify removals/reductions of CO_2 based on stock change accounting.

Liability for changes in carbon stocks on the land should be clearly established, tracked, and managed over time following GHG accounting and registry requirements for transparency. Contracts that engage traditional risk management methods can be used to ensure the replacement and/or funds to acquire replacement of any "non-permanent" forest-based credit. GHG contracts should assign liabilities for loss, loss mitigation, and counter-party obligations to disclose and register changes in registered carbon stocks.

Any or a combination of the following (or other identified) forest management practices has the potential to increase and maintain overall forest carbon stocks in Washington forests:

- Programs, incentives and development of new markets (e.g. increasing demand for large solid wood beams) for increased lengths of harvest rotation.
- Improved restocking of under-stocked areas/Reforestation of non-forested areas that were historically in forest cover, both utilizing native tree species.
- Silvicultural techniques to improve carbon sequestration rates.
- Appropriate thinning of over-stocked areas (also addressed in F-1).
- Avoidance of conversion to non-forest uses (covered in F-2).
- Enhance/incentivize riparian restoration outside of commercial forest areas.

Programs and incentives in support of these methods of practice could include:

- Participation in the development of regional and national carbon markets that allow

[9] The TWG does not anticipate this action to have large additional benefit. In addition there is a lack of information on available acreage. Therefore, this portion of the goal was not quantified.

participation by large and smaller forest landowners (allowing aggregation can facilitate small landowner participation).

- Increased use of conservation easements to maintain working forests managed for enhanced carbon sequestration and environmental values (see e.g. F-2 for more details on the use of conservation easements).
- New tax incentives or tax relief that encourage forest management for greater forest carbon stocks.
- Other identified forest landowner incentives and technical assistance programs that protect and preserve our forests and address the reality of increased ownership fragmentation.
- Development fees that fund on-site and/or off-site mitigation for identified climate impacts of projects.
- Third-party verified green building certification systems[10] that encourage and support use of wood products from managed and sustainable forestland sources that store additional carbon (see e.g. F-4, F-5 and RCI-3 for more details on how to include life cycle impacts in green building standards).

Increased rotations result in larger diameter logs, which are currently not as marketable within the state due to a lack of infrastructure for processing large diameter wood. Addressing infrastructure issues and marketability of larger logs is a key component to providing incentives for implementing longer rotations. Communities interested in diversifying their milling infrastructure would need to be supported through economic development financing.

Habitat restoration, particularly for salmon, can have net carbon benefits (i.e., additional carbon storage in soils and biomass, and in biomass accumulation in fish and wildlife populations due to expanding and improved habitat conditions). There is preliminary capability to model the impacts of recovery efforts, including quantifying additional carbon sequestration. Forest carbon protocol development efforts should consider these opportunities as well. (Note: the potential carbon sequestration from habitat restoration was not quantified below).

Additional analysis is needed to determine which combination of these or other programs and incentives would yield the most cost effective and environmentally sound absolute increases to levels of sequestered carbon in Washington forests.

Related Policies/Programs in Place

State Forest Practices Act and related regulations require prompt reforestation after harvest, and promote the maintenance of both healthy growing forests and a viable forest products industry.

Open Space Taxation laws provide property tax relief for lands kept in forest uses.

Federal land management law and policies for national forests lead toward development and protection of forests in older ages, which store more carbon.

[10] A complete definition of "third-party-verified green building certification systems" can be found in RCI-3. The terminology and definition are used consistently throughout the forestry options.

Growth Management Act rules and local growth management plans establish zones of important forest resources to be protected from urban and suburban development.

Legal and policy direction for state-owned forested trust lands direct that 10-15% of HCP planning areas (9 in the HCP planning area) be targeted for development of older forest conditions, and call for active forest management which promotes productive use of forest lands' growing potential, which in turn stores carbon.

Many forest landowners have voluntarily secured one or more forms of independent, third-party certification of sustainable forest management, which indirectly promotes storage of carbon in healthy growing forests and durable wood products, through adherence to comprehensive and detailed forest management standards

Types(s) of GHG Reductions

Increased carbon sequestration and storage in forest biomass and soils.

Estimated GHG Savings (in 2020) and Costs per $MtCO_2e$

			Reductions		($MMtCO_2e$)*		
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) $ millions**	**Cost-Effective-ness $/$tCO_2$**
F-3	Enhanced Carbon Sequestration in Forests	Increase productivity on 50% of available forest acres by 2020.	0.2	0.6	4.0	$107	$26

Data Sources:

Forest carbon stocks, sequestration rates, and growing stock volume from PNW defaults in the US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US, General Technical Report NE-343 (also published as part of the Department of Energy Voluntary GHG Reporting Program); data on distribution of forest types in eastern and western WA from USFS Forest Inventory Analysis; Assumptions about carbon removals during harvesting from Strong, T.F., 1997 "Harvesting Intensity Influences the Carbon Distribution in a Northern Hardwood Ecosystem," USFS Research Paper NC-329; costs of implementing forest management practices based on WA Department of Natural Resources Forestland Enhancement Program (FLEP) cost share rates.

Quantification Methods:

The Forestry Technical Working Group identified two primary opportunities in WA for increasing net forest carbon stocks (beyond what can be accomplished with avoided forest conversion, which is covered by option F-2). Those are afforestation that restores land to historical forest conditions and changes in forest management. The GHG benefits and costs/cost savings are quantified for the latter below.

Forest Management

The net change in carbon stocks in forest biomass and soil is influenced by growth, mortality and decay processes, as well as the amount of carbon removed during harvest. The potential exists to increase net forest and harvested wood carbon stocks on working forests in WA through a number of management practices that, in effect, either extend harvest rotations or increase stand productivity (or both). The later can be accomplished through, for example, stand fertilization, using genetically improved trees, and changes in stocking and thinning practices. These practices have the potential to increase the amount of carbon sequestered and stored in forest biomass (live trees, understory vegetation, standing and down dead trees, and small diameter debris on the forest floor), soils, and harvested wood products (HWP).

Increasing harvest rotations allows more time for forest growth before harvest, which can increase the volume of forest biomass, some portion of which is eventually harvested. The net impact of this practice on forest and HWP carbon stocks is complex and difficult to quantify. In addition, research is currently inconclusive in that studies have shown both increases and decreases in carbon stocks from extended rotation age. For these reasons, the impacts of extended age rotation were not quantified.

Increasing productivity involves increasing the rate at which forests accumulate biomass; i.e., a high productivity stand accumulates more carbon in biomass over the same amount of time as an otherwise equivalent low productivity stand. This leads to a relatively higher growing stock volume (i.e., the volume of living trees above the ground), some portion of which is harvested at periodic intervals (providing for potentially greater harvest volumes). Data are available to estimate the carbon stock changes associated with increasing forest productivity in WA, thus the analysis of GHG benefits of forest management is based on this process, and it is intended to represent at least the partial potential for increasing net carbon stocks in WA forests.

The net impact of a shift from low to high productivity forests involves both forest carbon and HWP pools. From a carbon accounting perspective, harvested carbon represents a carbon stock loss to the forest and a carbon stock gain into the HWP pool, with only a portion of the carbon that is shifted into the HWP pool at harvest remaining stored for long periods of time. Options F-3 and F-4 are essentially divided along the accounting boundary between the forest and HWP carbon pools, with F-3 focusing on gains in forest carbon stocks (biomass and soils) and F-4 focusing on gains in HWP carbon stocks. The change in carbon stocks in both forest and HWP pools are quantified below, with the carbon stock increases within the forest boundary reported under F-3 and the carbon stock changes in HWP reported under F-4.

The potential increase in net carbon stocks resulting from improving stand productivity on timberlands in WA is estimated below using the following key factors calculated from published carbon stocks and growing stock volumes (USFS GTR NE-343):

Incremental increase in carbon stocks when stand productivity increases (0.3 tons C/ac/yr)

Incremental increase in growing stock volume when stand productivity increases (2,786 cubic feet/ac)

These values, combined with assumptions about harvest rates, are used to estimate the incremental increase in forest carbon and harvested carbon removed from forests in stands that have been treated with management practices that increase productivity. In addition, the amount of carbon remaining stored in the increased portion of harvested carbon is tracked using established accounting methods for estimating long-term carbon storage in durable HWP.

These factors are applied to an approximate area of forestland in WA where the potential exists to increase forest productivity, based on the area of timberlands that are currently classified as having relatively low productivity (as measured by site productivity index).

Increases in Carbon Sequestration Rates and Growing Stock Volumes

The USFS publishes carbon stock tables for forest types by region for the entire US. In some regions, for some forest types, the USFS provide tables for both average and high productivity stands. Such tables are available for Douglas fir forests in the western region of the Pacific Northwest ("PNW W"). Douglas fir forests are the most abundant type in Washington, distributed close to evenly between east- and west-sides of the state, and an analysis of this forest group alone is believed to be a good approximation of the overall potential GHG benefits of forest management in WA. Given the available data for the PNW W and the abundance of Douglas fir forests, the analysis focuses on the impacts of increasing productivity of Douglas fir in western WA.

Carbon stock and growing stock volume data in the USFS tables (see F Table 10 and F Table 11 below) were used to calculate an annual carbon sequestration rate for average and high productivity Douglas fir forests in western WA (carbon stocks in 75 yr old stands were subtracted from carbon stocks in new stands and divided by 75). An average over 75 years is assumed to encompass the range of actual age classes for this forest type in western WA, thereby providing a representative average (in reality, sequestration rates vary by stand age). Note that soil carbon stocks are constant over time and between productivity classes, so carbon stock gains occur only in biomass pools. The high productivity stands sequester approximately 0.3 tons more carbon per acre per year. Therefore, regardless of the initial carbon stock levels, a forest stand that moves to higher productivity status will gain roughly 0.3 more tons C per acre per year than it would if left as is.

F Table 10. Carbon stocks and mean growing stock volumes by selected age class for Douglas fir forests in the PNW W (USFS GTR NE-343, Table A22)

Age	Mean volume (cf/ac)	Soils (tC/ac)	Biomass (tC/ac)	Total (tC/ac)
0	0	38.3	33.3	71.6
35	5600	38.3	105.5	143.8
45	7927	38.3	135.0	173.3
50	8954	38.3	148.0	186.3
55	9981	38.3	160.9	199.2
75	13432	38.3	204.4	242.7
95	16213	38.3	239.5	277.8
Average annual sequestration (75 year average) (tC/ac/yr)				2.3

F Table 11. Carbon stocks and mean growing stock volumes by selected age class for High Productivity Douglas fir forests in the PNW W (USFS GTR NE-343, Table A23)

Age	Mean volume (cf/ac)	Soils (tC/ac)	Biomass (tC/ac)	Total (tC/ac)
0	0	38.3	32.9	71.2
35	6370	38.3	104.9	143.2
45	10272	38.3	148.4	186.7
50	11740	38.3	164.7	203.0
55	13207	38.3	180.9	219.2
75	17518	38.3	228.9	267.2
95	20756	38.3	265.2	303.5
Average annual sequestration (75 year average) (tC/ac/yr)				2.6

In addition, the growing stock volume is greater in all age classes of high productivity Douglas fir stands. Assuming that, on average, stands are harvested at 50 yrs, USFS HWP accounting methods were used to convert the 2,786 cubic feet per acre incremental increase in growing stock volume into the equivalent carbon volume of 32.2 tons C/ac (see F Table 17 and Appendix below for explanation of this calculation). Note that this is the carbon stored in the incremental increase in growing stock, only a portion of which is removed during harvest (this analysis assumes 35% is removed, see below).

Forestland with the Potential to Increase Productivity

Data on the area of Douglas fir timberlands in WA by site productivity class where collected from the USFS Forest Inventory and Analysis database for 2005 and used to approximate the potential acreage on which productivity can be improved (F Table 12). The potential acreage is based on the number of acres of Douglas fir on the Westside in site productivity classes less than 120 board feet per acre (need to double-check units for site class). These data suggest a potential of approximately 1,086,464 acres.

F Table 12. Area of Douglas fir timberlands in WA, by region and site productivity class.

Site productivity class (board feet/ac?)	Eastside (acres)	Westside (acres)	Total (acres)
225+	13,806	204,183	217,989
165-224	53,501	1,434,749	1,488,250
120-164	237,556	1,873,005	2,110,561
85-119	512,208	698,235	1,210,443
50-84	1,454,295	314,283	1,768,578
20-49	942,830	73,946	1,016,776
Total	3,214,195	4,598,401	7,812,596

It was assumed that productivity could feasibly be increased on only 50% of these acres by 2020 and that an equal portion (41,787 acres) would be treated each year from 2008 to 2020.

Calculation of Net Carbon Stock Change in Forests and HWP

The calculation of net forest carbon stock change takes into account that each year gains in biomass carbon stocks from higher accumulation rates are offset by the removal of larger volumes of carbon during harvest (F Table 13). The incremental increase in biomass carbon stocks is calculated by multiplying the cumulative number of acres treated by 0.3 tons C/ac/yr (F Table 13, Column A). Cumulative acres are used because once an area is treated it continues to sequester carbon at a higher rate in subsequent years.

The incremental increase in carbon removed during harvest is calculated by multiplying the number of acres harvested each year by 35% of the carbon in the growing stock volume (i.e., 35% of 32.2 tons C/ac) (F Table 13, Column B). This assumes that 35% of the growing stock volume is removed during a harvest (based on a study of carbon removals at different harvest levels; 35% is roughly the proportion removed from moderate harvest levels, see Strong 1997 for details). The number of acres harvested is calculated by assuming 3% of the 41,787 acres treated each year are harvested the following year. The carbon removed during harvest is subtracted from the carbon gains in biomass due to sequestration to yield a net change in forest carbon stocks each year (F Table 13, Column C). If the calculation stopped here, then this would imply that all carbon removed is essentially emitted to the atmosphere. Therefore, a subsequent step is taken to account for the portion of carbon that remains stored in HWP for a total carbon stock balance.

Standard USFS HWP accounting methods were used to estimate the incremental increase in carbon that remains stored in HWP indefinitely. The amount of carbon stored in HWP carbon stocks is time dependent relative to the year of harvest (carbon stocks are high initially and decrease over time), making carbon stock accounting for HWP complex. Therefore, an approach has been developed to standardize and simplify HWP carbon accounting, which applies the amount of carbon still stored in HWP 100-yrs after harvest as the estimated net change in HWP carbon stocks attributable in the year of harvest.

Using the USFS methods, a coefficient of 6.9 tons C/acre was calculated for the amount of carbon that remains stored in HWP 100-yrs after harvest of the increased growing stock volume due to higher productivity (see F Table 20 and Appendix below for calculation details). For this analysis it is assumed that 35% of the growing stock volume is harvested, which would lower the actual amount of additional carbon stored to 2.4 tons C/acre (35% of 6.9 tons C/ac). The net annual carbon stock increase in HWP attributable to increased productivity was calculated by multiplying the number of acres harvested annually (3% of 41,787 acres) by 2.4 tons C/acre (F Table 13, Column D). For standardization across all policy options, units are converted to million metric tons carbon dioxide equivalent (MMtCO_2e) in

F Table 14.

F Table 13. Summary of Calculated Net Changes in Forest and HWP Carbon Stocks (in units of tons C)

			Column A	**Column B**	**Column C (A minus B)**	**Column D**	**Column E (C plus D)**
Year	Acres/yr	Cumulative Acres	Increased C Stocks in Forest Biomass (tons C)	Increased C Stocks Removed at Harvest (tons C)	Net Change in Forest Carbon Stocks (tons C)	Net Increase in HWP C Stocks (tons C)	Combined Carbon Change of F-3 and F-4 (tons C)
2008	41,787	41,787	13,873	0	13,873	0	13,873
2009	41,787	83,574	27,747	14,118	13,629	3,008	16,637
2010	41,787	125,361	41,620	14,118	27,502	3,008	30,511
2011	41,787	167,148	55,493	14,118	41,375	3,008	44,384
2012	41,787	208,935	69,367	14,118	55,249	3,008	58,257
2013	41,787	250,723	83,240	14,118	69,122	3,008	72,131
2014	41,787	292,510	97,113	14,118	82,995	3,008	86,004
2015	41,787	334,297	110,987	14,118	96,869	3,008	99,877
2016	41,787	376,084	124,860	14,118	110,742	3,008	113,750
2017	41,787	417,871	138,733	14,118	124,615	3,008	127,624
2018	41,787	459,658	152,606	14,118	138,489	3,008	141,497
2019	41,787	501,445	166,480	14,118	152,362	3,008	155,370
2020	41,787	543,232	180,353	14,118	166,235	3,008	169,244
Total	543,232		1,262,472	169,414	1,093,058	36,102	1,129,159

F Table 14. Summary Table: Results in Million Metric Tons Carbon Dioxide Equivalent ($MMtCO_2e$)

	Net Change in Forest Carbon Stocks ($MMtCO_2e$)	Net Increase in HWP C Stocks ($MMtCO_2e$)	Combined Carbon Change of F-3 and F-4 ($MMtCO_2e$)
2008	0.05	0.00	0.05
2009	0.05	0.01	0.06
2010	0.10	0.01	0.11
2011	0.15	0.01	0.16
2012	0.20	0.01	0.21
2013	0.25	0.01	0.26
2014	0.30	0.01	0.32
2015	0.36	0.01	0.37
2016	0.41	0.01	0.42
2017	0.46	0.01	0.47
2018	0.51	0.01	0.52
2019	0.56	0.01	0.57
2020	0.61	0.01	0.62
Total	4.01	0.13	4.14

The results suggest potential net carbon stock increases in forest biomass of 0.20 $MMtCO_2e$ in 2012, increasing to 0.61 MMt CO_2e in 2020 as more acres are treated, with a cumulative gain in forest biomass carbon stocks of 4.01 $MMtCO_2e$ from 2008-2020. In addition, the analysis suggests a net carbon stock increase in HWP of 0.01 MMt CO_2e each year, for a cumulative gain of 0.13 $MMtCO_2e$ from 2008-2020.

Costs Analysis

The implementation mechanisms above are general and flexible. They do not prescribe a specific program and recognize that a number of parties could share in the cost of implementing new management practices (i.e., landowners, incentive programs, technical assistance providers, etc). In this analysis costs are based on the average cost of implementing forest management practices on the ground that have the potential to increase productivity. These data are readily available from existing technical assistance programs.

The implementation mechanisms also recognize the role of market mechanisms in proving incentives to change forest management practices. It is generally the case with such market mechanisms that costs to one entity represent cost savings to another. Therefore, the net impact of market mechanisms on societal costs is assumed to be zero.

An "average" cost to implement forest management practices was derived from WA Department of Natural Resources Forest Land Enhancement Program cost share information. WA DNR publishes acceptable levels of cost by different forest management practices for program eligibility. The range of costs for forest stand improvement is $45 to

\$475[11] per acre. The specific practices include releasing brush competition, non-commercial thinning at several intensity levels, pruning, fertilization, and prescribed underburn. The actual practices needed to enhance production will vary site to site and this option does not attempt to prescribe implementation of specific practices. Therefore, the midpoint of the range of costs above (\$260/acre) was chosen to reflect the average cost to implement forest management.

The average cost to implement forest management was multiplied by the number of acres treated each year to yield an average annual cost of \$10.9 million (F Table 15). Annual discounted costs were estimated each year from 2008 to 2020 using a 5% discount rate. The sum of annual discounted costs from 2008 to 2020 provides an estimate of the Net Present Value (NPV) of this option, which amounts to \$107 million. The cumulative cost effectiveness of the total program was calculated by dividing the NPV by cumulative carbon benefits of this option for, yielding \$26/ton CO2e. Because the GHG benefits of improved forest management span F-3 and F-4. Total GHG benefits of these options combined were used to calculate cost effectiveness.

F Table 15. Summary of Cost and Cost Effectiveness

	Acres	Total GHG Benefit (F-3 and F-4)	Cost	Discounted Costs
2008	41,787	0.05	\$10,864,644	\$10,864,644
2009	41,787	0.06	\$10,864,644	\$10,347,280
2010	41,787	0.11	\$10,864,644	\$9,854,553
2011	41,787	0.16	\$10,864,644	\$9,385,288
2012	41,787	0.21	\$10,864,644	\$8,938,370
2013	41,787	0.26	\$10,864,644	\$8,512,733
2014	41,787	0.32	\$10,864,644	\$8,107,365
2015	41,787	0.37	\$10,864,644	\$7,721,300
2016	41,787	0.42	\$10,864,644	\$7,353,619
2017	41,787	0.47	\$10,864,644	\$7,003,447
2018	41,787	0.52	\$10,864,644	\$6,669,949
2019	41,787	0.57	\$10,864,644	\$6,352,333
2020	41,787	0.62	\$10,864,644	\$6,049,841
Total	543,232	4.14		\$107,160,722

The analysis does not account for potential increases in forest revenue as a result of greater harvest volumes and strong forest products markets. If this were taken into account, the net costs of the option would be lower or possibly even negative.

Appendix: Calculations of HWP assumptions

Two key HWP coefficients were calculated using standard USFS methods:

[11] This includes the cost of non-commercial thinning at the highest intensity level, plus the cost of slash disposal.

The incremental increase in carbon in the growing stock volume of forests treated to improve productivity (32.2 tons C/ac, see F Table 17)

Of this, the amount of that carbon that remains stored in products in use and landfills 100-years after harvests (6.9 tons C/ac, see F Table 15)

The USFS methodology uses growing stock volume in metric units as a starting point. The incremental increase in growing stock volume of high productivity stands was used as a starting point for this analysis: 2,786 cubic feet per acre converts to 192 cubic meters per hectare (m3/ha). Thus, all factors calculated below represent increases above baseline productivity levels.

A series of default coefficients for the PNW W region were applied to the 192 m3/ha to apportion the fraction of growing stock volume into classes of softwoods and hardwoods (F Table 16). The specific gravity of hardwoods and softwoods are combined with the carbon content in biomass to calculate separate per-area carbon volumes for hardwood and softwood classes (F Table 17).

F Table 16. Softwood and Hardwood fractions in Douglas fir PNW W growing stock (US GTR NE-343 Table 4)

	Factor
Incremental increase in growing stock volume (m3/ha) (i.e., 4,086 cuft/ac converted to metric units)	192
Fraction of growing stock volume that is softwood	0.959
Fraction of softwood growing stock volume that is sawtimber-size	0.914
Fraction of hardwood growing stock volume that is sawtimber-size	0.415
Specific gravity of softwoods	0.44
Specific gravity of hardwoods	0.426
Carbon content in biomass	0.5

F Table 17. Calculated Carbon Content of Softwood and Hardwoods Harvested from Douglas fir Forests in the PNW W

	Tons C/ha
Softwood saw log carbon in growing-stock volume	36.95
Softwood pulpwood carbon in growing-stock volume	40.43
Hardwood saw log carbon in growing-stock volume	0.69
Hardwood pulpwood carbon in growing-stock volume	0.98
Total (tC/ha)	79.06
Total (tons C/ac)	32.18

The quantity of carbon in hardwoods and softwoods that is processed into primary wood products was calculated next (factoring out carbon in logging residue, fuelwood, and waste), using the ratios in F Table 18 for the Pacific Coast region of the US. The results are approximate per-area carbon stocks (tons carbon per hectare) in industrial roundwood, excluding bark and fuelwood (F Table 19).

F Table 18. Ratios of Industrial Roundwood produced from Hardwood and Softwood classes in the Pacific Coast Region of the US (USFS GTR NE-343 Table 5)

	Ratio of industrial RW to growing stock volume removed as RW	Ratio of carbon in bark to carbon in wood	Fraction of growing stock volume removed as roundwood	Ratio of fuelwood to growing stock volume removed as RW
Softwood Saw log	0.965	0.181	0.929	0.096
Softwood Pulpwood	1.099	0.185	0.929	0.096
Hardwood Saw log	0.721	0.197	0.947	0.957
Hardwood Pulpwood	0.324	0.219	0.947	0.957

F Table 19. Calculated Carbon Content of Harvested Wood that Produces Industrial Roundwood

	(tons C/ha)
Softwood saw log carbon in industrial roundwood	33.13
Softwood pulpwood carbon in industrial roundwood	41.28
Hardwood saw log carbon in industrial roundwood	0.47
Hardwood pulpwood carbon in industrial roundwood	0.30

The average disposition pattern of HWP over time in the PNW W is provided by the USFS methodology. The disposition pattern tracks the flow of softwood and hardwood classes of industrial roundwood through four "pools" over time: carbon in HWP in use, carbon in HWP in landfills, carbon in HWP emitted with energy capture, and carbon in HWP emitted without energy capture. Disposition patterns are provided separately for softwood and hardwood categories and are represented by the fraction of carbon remaining in each pool over time.

F Table 20 shows the fraction remaining 100-years after harvest for the PNW W by softwood and hardwood classes. These fractions were multiplied by the corresponding initial carbon contents shows in F Table 19 to yield the carbon content remaining 100-yrs post harvest in each pool. The net carbon stock change in HWP is calculated as the total amount of carbon remaining in HWP in use or landfills after 100-yrs.

F Table 20. Fraction of Carbon in HWP Pools 100-yrs Post Harvest (USFS GTR NE-343 Table 6) and Corresponding Calculated Per-area Carbon Stock.

	Disposition Factor for 100-yrs	**Carbon Stock (tons C/ha)**
Softwoods-Sawlog		
in use	0.13	4.31
landfill	0.279	9.24
energy	0.242	8.02
emitted w/o energy	0.349	11.56
Softwoods-Pulpwood		
in use	0	0.00

landfill	0.076	3.14
energy	0.569	23.49
emitted w/o energy	0.355	14.65
Hardwoods-All		
in use	0.03	0.02
landfill	0.177	0.14
energy	0.448	0.35
emitted w/o energy	0.345	0.27
Total stored C 100 yrs post harvest (tons C/ha)		16.85
Total stored C 100 yrs post harvest (tons C/ac)		6.86

Key Assumptions: None cited

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): To the extent that the productive capacity of forest lands continues to be fully utilized to produce woody biomass, in the context of healthy native forest ecosystems, contributions to GHG sequestration and storage will continue past 2020.

Job Creation: All the methods of reforestation and forest management analyzed in this option create jobs, especially in rural areas.

Reduced Fuel Import Expenditures: Biomass produced for energy and biofuels are discussed under other options.

Key Uncertainties

The estimates above provide a coarse assessment of the GHG reduction potential. The real potential gains in carbon sequestration from changes in forest management will vary from site-to-site and depend on the specific practices implemented. The estimates assume that low productivity sites can be improved into high productivity sites. In reality, productivity may be limited by biophysical factors and other site conditions.

Additional Benefits and Costs

Increased timber yields and revenues.

Treating these stands could improve forest health and diversity

Maintaining productive forest sites with high standing carbon stocks can contribute to forest habitat and biodiversity, watershed protection, air quality, and recreation opportunities.

Employing more people in forest-related jobs in sawmills, wood production facilities, etc. will contribute to local economies and sustain forests and thus the forest industry.

Feasibility Issues

Most land suitable for growing native forests outside developed areas are currently forested, limiting the opportunity for afforestation as a productive option. In some cases, marginal farmland that was originally forested could be reforested, but these opportunities are uncertain.

Most of the highest-productivity forest lands are already managed by large private forest landowners to take full advantage of the site's productive potential. Low-productivity lands may not respond well to intensive management practices.

Policy direction for national forests may limit active management to optimize carbon sequestration rates (but may also promote protection of older forests which store more carbon).

Some market forces may reduce the incentive of commercial forest landowners, large and small, to invest in silvicultural practices designed to increase standing volume and thus carbon storage, while other market forces, such as ecosystem service markets including for carbon sequestration and storage, may increase incentives

Diverging forest management objectives, including commercial forest management with sustainable harvest for wood products, or long term preservation of forests, as well as scientific debate over carbon-maximizing management regimes, may frustrate the ability to reach agreement on estimates of carbon benefits of forest management.

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-4 Enhanced Carbon Sequestration in Harvested Wood Products

Mitigation Option Description

This policy is focused on recognizing and improving the climate benefits of managing forests for wood production. Washington State is uniquely positioned to take advantage of the climate benefits of wood production- the native Douglas-fir forests have high productivity rates and extremely desirable structural characteristics for long-lived wood products. Washington State is in strategic location to provide efficient sources of raw materials and has the infrastructure to manufacture these materials into products. The long-term carbon storage contribution of Washington State's wood product production is roughly 11.7 million metric tons CO_2e/yr, which offsets more than 10 percent of Washington's greenhouse gas emissions. Climate improvements can be made by incentives for increasing stand productivity to increase the amount of wood products that can be produced while maintaining carbon storage in the forest.

Mitigation Option Design

Goals: Implement forest management to improve productivity on 50% of available forest acres by 2020 (see also F-3).

Timing: See goals above. The demand for wood products should increase as the climate benefits of using a product with low embodied energy (in many cases a negative carbon footprint) is realized. See F-5 for more information on the expanded use of wood product for building materials.

Coverage of parties: Washington State Department of Natural Resources, University of Washington (Rural Technology Initiative), Washington State University (RTI, WSU Forestry Extension Program), USDA Forest Service, forest landowners (non-industrial, industrial, state, tribal, and federal), wood product manufacturing facilities.

Other: The long-term carbon storage contribution of Washington State's wood product production is roughly 11.7 million metric tons CO_2e/yr, which offsets more than 10 percent of Washington's greenhouse gas emissions. This does not include the avoided emissions of using wood products instead of more energy intensive substitute materials.

Implementation Mechanisms:

Full carbon accounting: all forestry carbon assessments should include wood product carbon storage as a mandatory pool along with above and below-ground biomass, litter, and soil carbon. It is an extension of the live tree carbon pool, just as litter and soil carbon is built upon the transfer of carbon from a formerly live tree. Without recognizing wood product storage as a carbon pool, an incomplete picture of the carbon cycle is given. Harvested wood product carbon storage can be calculated following guidelines published by the US Forest Service (Forestry Appendix, 1605b technical guidelines, also published in USFS GTR NE-343). Briefly, the guidelines lay out methodology starting from either a land-base (particular species and location) or a wood product. These methods use U.S. statistics to calculate a decay rate based on the proportion of a harvested log that goes into various forest and wood products, the half-life of different types of housing and other wood product end-uses, and the distribution of different kinds of wood products across these end-use categories. The portion of product (or log if starting from the forest) that remains “in-use” after 100 years can be considered long-term carbon storage, as described in the “100-Year Method” (Miner 2006). This methodology is applied in conjunction with F-3 to estimate the potential GHG benefits of this option.

Incentives for increasing productivity on Washington timberlands

These can include:

Increasing technical assistance for small family forest landowners, including funding for writing forest management plans. Currently about 10% of the 96,000 small family forest owners have a written management plan. The Department of Natural Resources Small Forest Landowner Office (SFLO) houses the Forest Stewardship Program, which is uniquely suited to assist landowners in the development of Forest Stewardship plans. Currently the need for assistance, e.g. field foresters who can assist landowners in developing Stewardship plans, far exceeds the existing staffing capacity. Sufficient funds should be directed to the SFLO so that proper staffing is available to meet the planning needs of small family forest landowners. Technology assistance can also be achieved through re-funding the Rural Technology Initiative at the University of Washington. This program helps rural forest resource-based communities and landowners manage their forestlands using updated technology. The federal grant has recently run out, but the state could re-fund this program to continue the development of a mechanism that allows the transfer of technology to small family forest landowners.

Encouraging smart application of silvicultural treatments such as planting genetically improved seedlings, fertilization, thinning, and pruning. Management techniques can improve stand productivity for west-side Douglas fir forests by 30% (see yield tables B22 and B23 of the forestry appendix to DOE’s 1605b technical guidelines for comparison). This increase in productivity could increase the amount of timber available for harvest without reducing the carbon storage on the landscape. Incentives for active forest management can be achieved by including forest management in a voluntary carbon offset program in addition to conservation forestry, afforestation/reforestation, and avoided deforestation.

Encourage and Support Use of wood products in Buildings

Incentives for increasing recovery rates at mills would result in more carbon storage in long-term wood products with the same input of raw material. The wood products that result from improvements in recovery rates should be considered additional carbon storage.

Support and provide incentives for programs that recognize embodied energy and operational energy in the building process.

Encourage utilization of third-party-verified green building certification systems[12] to promote the construction and design of energy-efficient buildings. Provide incentives for use of these systems statewide for construction in the private sector. The state has a law for public buildings that

[12] A complete definition of “third-party-verified green building certification systems” can be found in RCI-3. The terminology and definition are used consistently throughout the forestry options.

recognizes third party certification and wood harvested under the Washington Forest Practice Act.

Provide tax credits for construction of a green building or rehabilitation of an existing structure to green building standards.

The state could provide incentives that encourage and promote the use of climate friendly products in both commercial and residential buildings and building materials. Promote the utilization of Washington State forest products as a means to promote the use of local materials with lower climate change impact.

Related Policies/Programs in Place

Forest Stewardship Program, run by the Department of Natural Resources Small Forest Landowner Office, offers advice and assistance to landowners with over 5 acres to help improve forests for timber production, forest health, wildlife and fish habitat, special forest products, water quality, aesthetics and fire safety. In addition to free on-site forest management advice from a Stewardship Forester, the program offers Forest Stewardship Planning Courses, cost-share programs to help with forest stewardship projects, and other educational programs and materials in cooperation with Washington State University Extension. See http://dnr.wa.gov/base/education.html#stewardship for more information.

The Forest Stewardship Coached Planning short course is one of the planning courses offered by the Forest Stewardship Program. A recent report noted that 96% of King County small landowner participants had a better understanding of forest management options, 72% implemented a forestry practice they would not have done otherwise, and 63% completed a written plan as a result of the course (see http://king.wsu.edu/forestry/documents/ForestStewardshipImpacts.pdf for full report).

The Rural Technology Initiative at the University of Washington was established in 2000 by a federal grant to accelerate the implementation of new technologies in rural forest resource-based communities, such as GPS, GIS, and forest growth simulation models.

Types(s) of GHG Reductions

GHG reductions would be in the form of increased long-term storage of carbon in the form of wood products. In addition, GHG reductions would be achieved in the form of avoided emissions for using a wood product that take less energy to manufacture than an alternative material such as concrete or steel. See F-5 for more information on the climate benefits of wood product consumption.

Estimated GHG Savings (in 2020) and Costs per $MtCO_2e$

			Reductions		($MMtCO_2e$)*		
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) \$ millions**	**Cost-Effective-ness \$/tCO_2**
F-4	Enhanced Carbon Sequestration in Harvested Wood Products	Increase productivity on 50% of available forest acres by 2020.	0.01	0.01	0.1	*Quantified in coordination with F-3*	

See F-3 Estimated GHG Savings and Costs per $MtCO_2e$ for Forest Management for methodology details

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): None cited

Job Creation: None cited

Reduced Fuel Import Expenditures: None cited

Key Uncertainties

See F-3

Additional Benefits and Costs

None cited

Feasibility Issues

None cited

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-5. Expanded Use of Wood Products for Building Materials

Mitigation Option Description

This policy seeks to enhance the use of long-lived wood products as a strategy for reducing GHG emissions. Wood products not only store significant amounts of carbon but they are also less energy intensive to manufacture than substitute materials. The climate benefits of using wood products as opposed to substitute materials have been documented in numerous life cycle assessments.

Enhancement of wood product use can be achieved through transparent inclusion of carbon footprint/embodied energy information in green building standards and in consumer literature. Any increase must be done with consideration of practical use of the material and of material costs.

Mitigation Option Design

Goals: To expand the use of wood products for building materials, where appropriate (not quantified)

Timing: None cited

Coverage of parties: Builders, building material suppliers, wood product industries, recycled building material sellers, home improvement stores and consumers. All state agencies should lead through example.

Other: Wood products not only serve as long-term carbon storage but also require much less energy to manufacture than substitute materials such as concrete or steel. This difference in energy use is so significant that one study found a substitution for steel and concrete framing representing 6 to 8 percent of the total house weight resulted in an increase in greenhouse gas emissions of 26 to 31 percent respectively[13]. Other studies have echoed these same results. Eriksson's (2003) compilation of building life cycle assessments (LCAs) concluded that using wood-framed housing in the 1.7 million housing starts in Europe[14] would save 35-50 MMtCO_2e, which would be enough to contribute 11-16% of the emissions reduction needed for Europe to meet the Kyoto requirement. Buchanon and Levine (1999) report that a 17% increase in wood usage in the New Zealand building industry could result in a reduction of 484,000 MMtCO_2e. This reduction is equivalent to a 20% reduction in carbon emissions from the New Zealand building industry and roughly a 1.8% of New Zealand's total GHG emissions. Miner et al (2006)

[13] Taken from the CORRIM study, Perez-Garcia, Bruce Lippke, David Briggs, James Wilson, James Bowyer and Jaime Meil. 2005. The Environmental performance of renewable building materials in the context of residential construction. *Wood and Fiber Science* 37, CORRIM Special Issue: 3-17.

[14] Currently only 5% of new construction in Europe uses wood framing

report that, according to the CORRIM work, if 1.5 million housing starts in the U.S. used wood framed houses rather than non-wood building systems, 9.6 $MMtCO_2e$ per year would be kept out of the atmosphere. This savings is equivalent to keeping roughly two million cars of the road for one year.

Implementation Mechanisms:

Third party-verified green building certification systems[15]: Support green building standards that include embodied energy/carbon footprint/life cycle assessment (LCA) differentiation for building materials. The information can be included through the deployment of material selection LCI tools, such as the ATHENA® EcoCalculator for Assemblies or BREEAM's Green Guide to Building Assemblies. The ATHENA® EcoCalculator compiles greenhouse gas emissions for different material building assemblies (e.g. exterior walls, roofs, windows, floors, interior walls) based on detailed life cycle assessments using the ATHENA® Impact Estimator for Buildings. The ATHENA® Impact Estimator, in turn, uses data from the US Life Cycle Inventory Database and ATHENA®'s own datasets (see http://www.athenasmi.ca/tools/docs/EcoCalculatorFactSheet.pdf for more detail). The EcoCalculator tool is the free generic version of a tool commissionsed by the Green Building Initiative (GBI) for use in the Green Globes™ environmental assessment and rating system for commercial buildings. It is used by architect firms and universities and can be used for new construction, retrofits and major renovations in industrial, office or residential designs. BREEAM's Green Guide to Building Assemblies is used in BREEAM's Ecohomes program, which is the United Kingdom's predominant green building standard. Like the EcoCalculator, it uses LCA information to grade material assemblies. Building assemblies that have a high grade are awarded points towards the green building scheme. Note: this implementation mechanisms complements the life cycle emissions implementation mechanism explained in RCI-3.

Carbon footprint literature: Include carbon footprint information/literature on materials in building supply and home improvement stores. This information would show the consumer the total GHG emissions associated with a particular product. Life cycle assessments have already been done on many building materials (e.g. see ATHENA's EcoIndicator calculator) and these results can be included in the literature without having to do extensive LCAs on individual products. Note: this mechanism complements the carbon labeling mechanism explained in the RCI-8 straw proposal; however this method may be less costly than instituting a comprehensive carbon labeling scheme and can be used as an interim program while the rules of carbon labeling are developed.

Product life-time: Provide incentives to increase salvage of reusable building materials. Washington State has a number of used building material stores. The Northwest Building Salvage Network estimates that its four member stores in Seattle and Bellingham divert 1800-3600 tons of reusable building materials from the waste stream each year. Incentives, in the form of tax breaks or grants, should be put in place to encourage more building salvage material stores and online exchanges and to promote the use of existing stores with architects, builders and do-it-yourself home remodelers.

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[15] A complete definition of "third-party-verified green building certification systems" can be found in RCI-3. The terminology and definition are used consistently throughout the forestry options.

State adopted policies: the state should adopt policies that require the use of climate friendly materials in the construction and maintenance of all state buildings when those products are feasible and relatively close in price (within 5%) to the alternative.

Education/Outreach: Develop information and education programs to promote product substitution (using wood products wherever feasible) and the benefits gained through carbon sequestration and avoided emissions.

Related Policies/Programs in Place

Third party-verified green building certification systems: The state has adopted a number of green building standard bills. Executive Order 05-01 directs the adoption of green building practices in the construction of new or renovated state buildings (>25,000 ft2) and requires the achievement of LEED silver standards for WA public buildings. The High-Performance Public Buildings bill (Chapter 39.35D RCW) requires all new state-funded facilities over 5,000 ft2 to meet green building standards. Specifically, major office and higher education facilities will be required to achieve LEED Silver certification. However, because the LEED standards do not yet include embodied energy/carbon footprint consideration for material selection, other building materials, such as steel, are more favorable in the LEED point system. These current bills may not achieve the desired results of promoting the use of building materials with low carbon footprints.

The High-Performance Public Buildings bill does prioritize the use of locally extracted and manufactured products in all state building products. This emphasis may encourage the use of wood products produced in Washington State.

Reusable Building Materials

The Northwest Salvage Buildings Network, http://www.nwubm.net, has partnerships with Seattle Public Utilities, The Seattle Fleets and Facilities Department, the Seattle Department of Planning and Development and the Department of Ecology. NBSN's web site has useful information on salvage building product stores and on-line exchanges by city and region, http://www.nwubm.net/links.htm. In September 2007, the Department of Ecology Green Building Group and the City of Seattle Department of Planning and Development published a guide to Salvage and Reuse as part of a series on green home remodeling, http://www.ecy.wa.gov/pubs/0704017.pdf.

Types(s) of GHG Reductions

Displaced emissions associated with the manufacture and use of non-wood building materials (i.e., steel and concrete)

Estimated GHG Savings (in 2020) and Costs per $MMtCO_2e$

This option is not quantified due to limited information on the potential to increase the amount of wood used in residential and commercial buildings in Washington

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): None cited

Job Creation: None cited

Reduced Fuel Import Expenditures: None cited

Key Uncertainties

Opportunities to expand the use of wood in residential and commercial buildings may be limited.

Additional Benefits and Costs

Employing more people in forest-related jobs in sawmills, wood production facilities, etc. will contribute to local economies and sustain forests and thus the forest industry.

Feasibility Issues

The implementation of this option is dependent on changes in fire and insurance codes that may prohibit (or effectively prohibit via costly requirements for heavy timber use) a switch from steel and concrete to wood as primary building materials. Technology has shown a progressive move away from solid wood products to lighter, less-expensive, plastics covered in a very thin layer of wood. This trend, along with the aforementioned regulatory barriers, may make it difficult to implement replacement of steel and concrete building materials with wood products in the near future.

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-6 Expanded Use of Biomass Feedstocks for Electricity, Heat and Steam Production

Mitigation Option Description

This policy option seeks to expand the combined heat and power production (CHP) at forest product manufacturing facilities, including pulp and paper mills and lumber mills. The expanded use of CHP can reduce greenhouse gas emissions by displacing the use of fossil energy in two ways: using waste heat or steam that is a combustion by-product, and powering CHP with woody biomass. Many forest product manufacturing facilities have the co-generation capability to produce steam for industrial processes and electricity for both on-site use and off-site export to the electrical grid system. Potential exists to more fully use existing capacity, improve the efficiency of existing CHP facilities through the replacement of aged recovery furnaces with high pressure systems or combined cycle gasification units, and expand new CHP capacity at forest product facilities. CHP can provide a low cost opportunity for new renewable energy investment and a means to utilize woody biomass harvested from forest fuel reduction treatments. Increased utilization of biomass generated from forest fuel reduction treatments will help to achieve the forest restoration goals identified in policy option F-1 to reduce forest fire risk. Prioritizing the use of local forest residues has the added benefits of reducing transportation related emissions and providing revenue to the local forest economy. Potential also exists to replace older inefficient fossil fueled boilers (often kept for stand-by or baseline power needs) with modern biomass boilers or other bio-fuel burning capability identified in F-7.

Mitigation Option Design

Goals:

Achieve 206 MW of additional CHP production at Washington State forest products facilities (paper and lumber/wood) by 2020, 50% of identified technical potential.[16] Achieve 309 MW of additional CHP production at Washington State forest products facilities (paper and lumber/wood) by 2035, 75% of identified technical potential.

Timing:

2010: Complete assessment of biomass generation capability for Washington State forest products facilities.

[16] This policy option goal has been established based on the technical potential as it represents the maximum potential power generation from combined heat and power unit operations in forest products facilities. It represents the true potential and any goals should be presented as a fraction of what is absolutely achievable. Using the economic potential may constrain the possibilities as a result of an economic framework that is no longer valid in the year 2020 and beyond.

2020: Achieve 50% of identified technical potential CHP capacity at Washington State forest products facilities (paper and lumber/wood).

2035: Achieve 75% of identified technical potential for CHP capacity at Washington State forest products facilities (paper and lumber/wood).

Coverage of parties:

Forest products manufacturing facilities including pulp and paper mills and lumber mills.

State and federal government

Other: None cited

Implementation Mechanisms

Incentives to Develop Biomass CHP

Provide technical assistance in assuring adequate biomass fuel supply to biomass plants such as business and technical assistance in reclaiming urban wood through building demolition and reclaim of waste wood, and utilization of other waste biomass streams for biomass fuel.

Provide incentives for business in economically depressed counties with biomass availability to use local and regional biomass supplies to develop biomass renewable energy projects. Incentives could be community assistance grants, technical assistance grants, etc.

Leveraging of attractive financing arrangements, tax benefits such as the existing sales and use tax incentive for machinery and equipment used for biomass cogeneration facilities (RCW 82.08.02565[17] and RCW 82.12.02565[18]), extending the existing sales an tax incentive for renewable energy to include biomass renewable energy (RCW 82.08.02567), and other incentives to promote biomass technologies.

Recognition of pulp mill recovery boiler power as a renewable biomass energy resource.

Provide a long-term stable supply of woody biomass by increasing availability from national and state forests. It needs to be recognized that biomass resources for power and raw materials for existing manufacturing operations are currently very limited. If this policy option (and F-7) are implemented in a manner that increases competition for existing resources, the financial viability of both the policy options and the existing forest products manufacturing sector could be compromised.

Interconnection issues

Removing high interconnection cost and regulatory access barriers similar to OR Public Utility Commission ruling under UM 1129.

Permitting and siting

Supporting state, county and city land use prescreening efforts to support siting.

[17] http://apps.leg.wa.gov/RCW/default.aspx?cite=82.08.02565

[18] http://apps.leg.wa.gov/RCW/default.aspx?Cite=82.12.820

Status of regulation of wood waste (particularly urban wood waste) is unclear; however some federal regulatory concepts in the future may make burning wood waste prohibitively expensive if boilers must be regulated as solid waste boilers.

Related Policies/Programs in Place

Proposed EPA MACT Rules for boilers and Ecology solid waste rules may result in limitations on the ability to use some types of woody biomass for combined heat and power under this option (F-6) and potentially for other cellulosic bio-products under F-7. Specifically urban wood (such as wood removed in demolition projects) may be subject to more restrictions than other forms of woody biomass.

Expanded use of biomass feedstocks for combined heat and power at existing facilities may trigger rigorous air quality permitting requirements such as New Source Review (NSR), Prevention of Significant Deterioration (PSD) and New Source Performance Standards (NSPS). Either existing facilities expanding their capacity or new facilities would be subject to these provisions, depending on the specific unit involved.

Types(s) of GHG Reductions

By expanding the utilization of biomass at forest product facilities in Washington for on and off-site electricity, heat, and steam use, the equivalent amount of new fossil-based energy will be displaced resulting in a more energy efficient energy production program and significantly less GHG production per MWh generated.

Estimated GHG Savings (in 2020) and Costs per $MtCO_2e$

			Reductions		$(MMtCO_2e)$*		
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) $ millions**	**Cost-Effective-ness $/tCO_2$**
F-6	Expanded Use of Biomass Feedstocks for Electricity, Heat and Steam Production	206 MW by 2020	0.13	0.6	3.4	-$85	-$25

Note: Quantification of this policy option is based on analysis conducted by the ES TWG for ES-7. Quantification for this option has been refined to reflect the F-7 policy option goal and data estimates specific to forest products facilities in Washington. See ES-7 for further documentation of quantification methodology.

Data Sources:

CHP Technical Market Potential for WA Forest Product Facilities

Combined Heat and Power in the Pacific Northwest: Market Assessment This 2004 report provides: 1) A comprehensive review of current CHP capacity in the Pacific Northwest including a database by each state; 2) A review of the economic and technical market potential for additional CHP; 3) A review of barriers and incentives to CHP; and 4) Recommended actions to increase CHP deployment. http://www.chpcenternw.org/NwChpDocs/Chp_Market-Assessment_In_PNW_EEA_08_2004.pdf

Estimation of the total Washington State technical potential for CHP in above report is based on:

- Identification of applications where CHP provides a reasonable fit to the electric and thermal needs of the user. Target applications were identified based on reviewing the electric and thermal energy consumption data for various building types and industrial facilities.
- Quantification of the number and size distribution of target applications. Several data sources were used to identify the number of applications by sector that meet the thermal and electric load requirements for CHP.
- Estimation of CHP potential in terms of megawatt (MW) capacity. Total CHP potential is then derived for each target application based on the number of target facilities in each size category and sizing criteria appropriate for each sector.
- Subtraction of existing CHP from the identified sites to determine the remaining technical market potential.
- The estimate of technical potential for CHP in forest product facilities in Washington provided by the above report is 412 MW. The contribution from lumber/wood and paper facilities is 61 MW and 351 MW respectively.

Displaced Electricity and Thermal Energy

- Thermal energy displaced by increased CHP heat capacity at forest product facilities in Washington:

F Table 21. Thermal Energy Fuel Sources[19]

Fuel Source	
Natural Gas	15%
Biomass	60%
Coal	0%
Electricity	10%
Oil	15%

Estimates were compiled from various sources including expert opinion[20,21] **and published reports.**[22,23,24]

[19] AF&PA is producing updated survey information on fuel sources which is expected to be available in early to mid-2008.

[20] G. Narum. 2007. Personal Communication.

[21] L. Matthews. 2007. Personal Communication.

[22] AF&PA 2007. Commitment, Leadership, and Continuous Improvement: AF&PA Response to Environmental Paper Network Issue Paper. October 2007.

[23] WSU Energy Program. 2001. 2000 Washington State Directory of Biomass Energy Facilities. WSUCEEP01053. September 2001. Available at: http://www.energy.wsu.edu/documents/renewables/01_053_Biomassdirectory.pdf

Emission factors for natural gas, biomass, coal, electricity, and oil are common factors for all WA CAT TWGs and are calculated based on Washington Inventory and Forecast .

Biomass Fuel Costs

Biomass fuel costs for the cost analysis were refined for this option based on TWG member input and the additional sources cited below.

F Table 22. Delivered Biomass Cost Estimates

Biomass Type	Delivered Cost ($/dry ton)
Pulpwood[1]	35
Chipwood[1]	60
Sawdust[1]	33
Shavings[1]	24
Bark[1]	18.5
Mill Chips[2]	32
Forest biomass[2]	72
National Average[3]	51
Total Average	**40.7**
Total Weighted Average (Based on 50% Forest Biomass and 50% Mill Residues sources)	**52.9**

[1]D. Vaagen. 2007. Personal Communication.

[2]McNeil Technologies, Inc. 2003. Biomass Resource Assessment and Utilization Options for Three Counties in Eastern Oregon. Oregon Department of Energy, Contract number: C03057, December 31, 2003. Estimates are from E. Oregon and given as delivered price per green ton

[3]Walsh, M. et al. 1999. Update 2000. Biomass Feedstock Availability in the United States: 1999 State Level Analysis.

Quantification Methods: Starting with an estimate of Washington's forest product facilities technical CHP potential in the Pacific Northwest, as provided in the *Market Assessment* report (Energy and Environmental Analysis Inc. 2004) referenced above, assumptions regarding the penetration of and fuel shares for new CHP systems, and estimates of future capacity of CHP developed under the policy, were generated. Estimates of the net GHG emissions reductions were based on the avoided electricity and thermal energy displaced by increased capacity for CHP developed under this policy (F Table 23) Cost estimates are based on the biomass CHP systems costs based on both the capital cost of equipment and the operation and maintenance costs provided in Energy and Environmental Analysis, Inc for Oak Right National Laboratory (2004) *Combined Heat and Power in the Pacific Northwest: Market Assessmen*t, the biomass fuel costs, and the avoided cost of displaced fuels for electricity and thermal energy production.

[24] Energy and Environmental Analysis, Inc for Oak Right National Laboratory (2004) *Combined Heat and Power in the Pacific Northwest: Market Assessmen*t. Available at: http://www.chpcenternw.org/NwChpDocs/Chp_Market-Assessment_In_PNW_EEA_08_2004.pdf

F Table 23. Estimated GHG Emission Reductions

Results	2012	2020
Electricity		
TOTAL Reduction in Electricity Sales (electricity output from CHP plus avoided electricity use in boilers/space heaters/water heaters)	214	981
Reduction in Generation Requirements	230	1,055
Gross GHG Emission Savings	**0.12**	**0.53**
Natural Gas		
Net Change in Gas Use (negative values denote increased use)	196	901
Net GHG Emissions (negative values denote increased emissions)	**0.01**	**0.05**
Biomass		
Net Change in Biomass Use (negative values denote increased use)	-1,824	-8,374
Net GHG Emissions (negative values denote increased emissions)	**0.00**	**-0.02**
Net Change in Biomass Use (negative values denote increased use)	-113970	-523345
Coal		
Net Change in Coal Use (negative values denote increased use)	0	0
Net GHG Emissions (negative values denote increased emissions)	**0.00**	**0.00**
Oil		
Net Change in Oil Use (negative values denote increased use)	196	901
Net GHG Emissions (negative values denote increased emissions)	**0.01**	**0.06**

Synthesis of biomass feedstock supply and demand, accounting for biomass supply use for this option is provided in F Table 39 of Appendix A of this document.

F Table 24. Biomass CHP System Cost Estimates (thousand 2005 dollars)

	2012	2020/all
Annualized Capital Costs	$ 5,516	$ 24,070
Annual Non-Fuel Operating and Maintenance Costs	$ 540	$ 3,304
Biomass Fuel Costs	$ 8,623	$ 39,595

F Table 25. Total Fuel Cost Savings from Displaced Heating Fuels for All Systems (thousand 2005 dollars)

	2012	2020/all
Natural Gas	$ 1,334	$ 6,124
Biomass	$ 2,594	$ 11,910
Coal	$ -	$ -
Electricity	$ 254	$ 1,165
Oil	$ 1,863	$ 8,556

Key Assumptions: Key assumptions are the CHP technical potential in Washington, the analysis is based on a technical potential of 412 MW (per the Market Assessment source above); this potential is assumed to grow at a rate of 1.6% per year based on consideration of growth in electricity use in the commercial and industrial sectors; and the potential can be realized at a rate of 2.5 – 4.9% [2.5% per year through 2012, increasing linearly to reach 4.9% in 2020] of total potential per year to reach the goals outlined in this policy option to achieve 50% of technical potential in forest product facilities by 2020.

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): Fossil fuel-based energy production will be displaced in proportion to the expansion of utilization of biomass for on and off-site electricity, heat, and steam use. The contribution to long-term GHG emission goals will be replacement of energy production with carbon-neutral sources and will help reduce imported petroleum products.

Job Creation: After initial installation of new biomass fueled units, employment would be similar to that supporting current facilities.

Reduced Fuel Import Expenditures: Fuel oil use at forest product facilities has fluctuated through the 1990s. For the most part, pulp and paper, rather than lumber mills burn oil for on-site energy use. It can be expected that on-site use of fuel oil and thereby fuel imports will be reduced as biomass use for CHP at forest product facilities is expanded.

Key Uncertainties

There are uncertainties in the quantitative analysis of this option, i.e., the difference between the technical potential and the economic potential. While expanded use of biomass for combined heat and power is technically possible to a much greater extent than at present, an analysis is needed of the economic feasibility. Specifically, for existing facilities to determine that it is economic to undertake more energy generation from biomass, the facility would likely need a mechanism to sell power generated from high pressure steam as well as having a use for the resulting low pressure steam (typically process heating or product drying).

There are also policy uncertainties with respect to the regulatory regime applicable to such units; whether participating facilities will be able to access the power grid to sell power (both issues described above); and the long-term availability of tax incentives. With respect to tax incentives, it can be noted that these can be created and changed by future legislatures during the time-frame contemplated by this option and may impact economic potential.

Additional Benefits and Costs

Generally newer technology will result in improved energy efficiency and environmental performance.

Feasibility Issues

During the past decade, the forest products industry has been subject to great deal of financial uncertainty with the result that funds for new capital investments are limited. Financial feasibility of new units is often assessed against the value of older, but still functional units.

Some facilities will encounter barriers to the sale of power to the grid.

There is a great deal of uncertainty regarding the regulatory status of biomass boilers and the types of biomass fuels that can be burned for power. This may trigger a wait and see approach that could delay potential new investments.

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-7 Improved Commercialization of Advanced Lignocellulosic Processes

Mitigation Option Description

This policy option seeks to develop and improve the implementation of biorefinery technology to convert wood biomass to biofuels and other chemicals that can substitute for petro-chemicals. This policy option seeks to promote a viable state bio-refinery industry including potential new stand alone facilities and measures that can be deployed at existing industrial facilities such as forest products manufacturing facilities. Initially, it can be expected that stand-alone refineries would produce ethanol for transportation fuels with the potential for other bio-products. Existing forest products facilities have the potential to produce ethanol, bio-products and as well as export renewable power (carbon neutral) to the grid (F-6). Current research has identified underutilized forest biomass as one of the largest potential sources for in-state biofuel feedstocks. Wood biomass can be converted into biofuels and used for transportation or other uses, offsetting the use for fossil fuels. One approach would involve converting cellulose and/or hemicellulose to ethanol, acetic acid and other valuable chemicals. A second approach is to use residual pulping liquors which can be gasified and the resulting synthetic gas converted to electricity, transportation fuels or high value chemicals. While advanced lignocellulosic technology for wood biomass conversion to biofuels and chemicals is believed to be feasible, further research and development are needed for full scale commercialization of these conversion processes. This option, in collaboration with the policy option AW-2, aims to increase the production of biofuels from biomass feedstocks and improve the commercialization of the conversion process. Biorefinery facilities which produce both biofuels and chemicals from wood biomass feedstocks may provide a means of production with the greatest economic potential. Estimates of biomass supply from logging residues, mill residues, pre-commercial thinning, and forest fuel treatments suggest that 5.6 Mt of dry biomass are potentially available annually in Washington. Biomass harvested from forest fuel treatment thinnings make up the largest fraction of potential biomass with estimates up to 3.7 Mt/yr in Washington. Increasing the utilization of biomass harvested from restoration treatments to reduce forest fire risk, similar to policy option F-6, will help to achieve the goals outlined in policy option F-1. This policy option will aim to promote sustainable forest management strategies which provide wood biomass for biofuels production while maintaining forest productivity, carbon storage, and integrity of forest ecosystems. Also, pulp and paper mill sludge (unuseable fiber from manufacturing and recycle processes) is now disposed of in landfills. Estimates are that 200,000 dry tons per year are available. While not a large quantity, this biomass source is already on-site and could be an important incremental material for facilities installing bio-refinery technologies.

Mitigation Option Design

Goals: Increase utilization of waste biomass for biofuels by 3 million dry tons per year for the production of 250 million gallons of biofuels per year by 2020.

Note: Policy options F-7 and AW-2 will be quantified together incorporating waste biomass from agricultural and wood biomass sources. For analysis it is assumed that 1.5 million dry tons of waste biomass utilized will be from forest biomass sources.

Road map to first commercial biorefinery.

Governor to establish a public/private partnership to explore establishment of a state bio-refinery.

Start 2008 – Complete 2011 Research and analysis to support construction of 1st Washington State biorefinery.

Identify and assess lignocelluloses conversion technologies on Washington State biomass.

Perform techno- economic analysis of most promising candidates to assess technical economic feasibility

Assess broad environmental impact by means of life-cycle analysis or other encompassing mechanism

Start 2010 – Complete 2012 Construct demonstration scale biorefinery facility with best technology – 100 tons/day biomass (~ 3 million gallons fuel year)

Start 2012 – Complete 2015 Construction commercial scale biorefinery (~4100 tons/day biomass) ~131 million gallons of fuel/ year

Timing: See goals above

Coverage of parties: Governor's Office, State Universities, and the private sector

Other: New conversion technology that is optimized for Washington State biomass may need to be developed. The timing for this type of development work would be longer than the horizon presented above.

Implementation Mechanisms:

Analysis work required prior to building the 1st biorefinery can be accomplished with grants to Universities and engineering firms. An industrial partner would need to take the lead on building the demonstration and commercial scale biorefinery. Universities and engineering firms engaged in the assessment would be part of the consortium to build and operate the demonstration unit.

Incentives may be required construct initial biorefineries. Two significant barriers for constructing a commercial facility are concerns about availability and cost of biomass feedstock and the risk of constructing the first facility running on the biomass mix unique to Washington State. Incentives that could overcome these barriers include the following:

Support for research and development of biorefinery technologies – especially as it pertains to use of Washington State biomass feedstock.

Incentive grants for construction of initial biorefineries

Tax break for biorefinery operations

Long term contracts with the state and federal government guaranteeing supply of biomass.

Support of biomass cost that recognizes environmental benefit of using biomass for fuel.

Subsidy of transportation fuel produced from biomass. Federal government is considering $1.06/gallon subsidy of ethanol produced from lignincellulosics.

Establish long-term availability of increased biomass feedstocks (see F-6) to meet the needs of the emerging biorefinery industry and existing manufacturing base.

Related Policies/Programs in Place

Washington State provides a variety of tax incentives to encourage the development of in-state production facilities, distribution services and retail sales facilities for biodiesel and ethanol fuels. These include 1) Special B&O tax rate provisions apply to the manufacturing and distribution of biodiesel and alcohol fuels, 2) Qualifying buildings and equipment used in the manufacturing of alcohol fuel, biodiesel are exempt from state taxes for a period of 6 years, and 3) Certain investments in buildings and equipment for ethanol or biofuel production are eligible for the deferral of state and local sales and use taxes.
http://www.sccd.org/policy/WashingtonBiofuelsIncentives.shtml

In 2006, the Washington State Legislature implemented a minimum renewable fuel content requirement. This requires that 2% of diesel fuel sold in Washington State be biodiesel and 25 of the gasoline sold in the Washington State be ethanol.
http://www.sccd.org/policy/RenewableFuelRequirement.shtml

Each year since 2002, the US Department of Energy and the US Department of Agriculture have jointly issued solicitations for the applications of financial assistance addressing research and development of biomass based products, bioenergy, biofuels and related processes. These solicitations are in fulfillment of the Biomass Research and Development Act of 2000 and the Energy Act of 2005. http://www.brdisolutions.com/default.aspx

Types(s) of GHG Reductions

CO_2: Lifecycle emissions are reduced to the extent that biofuels are produced are produced from forest residue with a lower embedded fossil-based carbon than conventional (fossil) gasoline. Feedstocks used for producing biofuels can be made from forest residues, which contain carbon sequestered during photosynthesis.

Estimated GHG Savings (in 2020) and Costs per $MtCO_2e$

			Reductions		($MMtCO_2e$)*		
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) $ millions**	**Cost-Effective-ness $/$tCO_2$**
F-7	Improved Commercialization of Advanced Lignocellulosic Processes	1.5 million dry tons by 2020	0.02	0.91	3.71	$261	$70

Data Sources: Lifecycle emission factors for gasoline and GHG reduction benefits of starch and cellulosic ethanol by fuel blend (E10 and E85) as compared to gasoline were obtained from Argonne National Laboratory's GREET model (v1.7). Conversion rate factors for generating cellulosic ethanol are based on personal communication from John Ashworth (NREL) to Steve

Roe (CCS) (April 2007). Production cost differential estimates for cellulosic ethanol as compared to starch ethanol are based on DOE EIA analysis[25]. The organic waste cost premium estimate for use of waste biomass feedstocks as compared to bioenergy crops is based on a report from the California Energy Commission (2001)[26].

F Table 26. Lifecycle Emission Factor for Gasoline[27]

Fuel	**Emission Factor** (MtCO2e/MMgal)
Reformulated gasoline	8,814

F Table 27. GHG Reduction Benefit of Ethanol by Feedstock and Fuel Blend[28].

Technology	**Fuel Blend**	**Normalized GHG Reduction Relative to Gasoline (100% blend)**
Starch Based Corn Ethanol	E10	15.0%
	E85	20.7%
Cellulosic Ethanol	E10	72.0%
	E85	97.9%

F Table 28. Incremental GHG Benefit of Cellulosic versus Corn Ethanol[29]

Fuel Blend	**Incremental GHG Benefit**
E10	57%
E85	77%

[25] DOE EIA analysis can be found at www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed January 2007.

[26] California Energy Commission (CEC). 2001. Costs and Benefits of a Biomass-to-Ethanol Production Industry in California. March 2001. Available at: http://www.energy.ca.gov/reports/2001-04-03_500-01-002+002A.PDF

[27] Argonne National Laboratory's GREET model (v1.7)

[28] Argonne National Laboratory's GREET model (v1.7)

[29] Estimates are calculated based on GHG reduction benefits reported in Argonne National Laboratory's GREET model (v1.7).

F Table 29. Cellulosic Ethanol Production Factors[30]

Time Period	Production Rate (gallons/dry ton)
2015 - 2020	90
2019 - 2020	100

Quantification Methods:

Policy options F-7 and AW-2 were quantified together using the same methodology. The GHG reductions and cost estimates provided below are attributable to the forest residue biomass utilized for cellulosic ethanol production. GHG reductions and cost estimates for cellulosic ethanol production from agricultural wastes and perennial bioenergy crops are documented in AW-2.

GHG Reductions

The benefits of this option are based on the incremental GHG benefit of production of cellulosic ethanol from forest biomass as compared to starch based corn ethanol. The benefits of using ethanol from starch-based production are accounted for as part of the analysis for T-11. Cellulosic ethanol production from forest biomass (

[30] J. Ashworth. 2007. Personal Communication with Steve Roe (CCS).

F Table 30) was determined based on forest biomass utilization goals established by this policy option and reported production rates of cellulosic ethanol (

F Table 29).

The GHG reductions are estimated based on the production of cellulosic ethanol at levels targeted in this policy option (

F Table 29), the lifecycle emission factor for gasoline (F Table 26), and the incremental GHG reduction benefit of cellulosic ethanol production over conventional starch-based ethanol. The incremental GHG reduction benefit of cellulosic ethanol production over conventional starch-based ethanol is based on the reported values from the GREET model (v1.7) (F Table 28) and reflects projections for the E85 market share through 2020. GHG reductions for this policy option are shown in F Table 31.

F Table 30. Assumed Cellulosic Ethanol Production Schedule

Year	Forest Residue Biomass Utilization (dry tons)	Cellulosic Ethanol Production (million gallons (MMgal))
2010	-	-
2011	-	-
2012	36,500	3.3
2013	219,438	19.7
2014	402,375	36.2
2015	585,313	52.7
2016	768,250	69.1
2017	951,188	85.6
2018	1,134,125	102.1
2019	1,317,063	118.5
2020	1,500,000	150.0

Estimates of forest residue utilization are based on goals and timing outlined for this policy option. By 2012, the target is construction of a demonstration scale biorefinery facility with best technology – 100 tons/day biomass (36,500 dry tons/year) (~ 3 million gallons fuel year). By 2020, the target is construction of a commercial scale biorefinery utilizing 1.5 million tons biomass/year. Cellulosic ethanol production is assumed to increase linearly from 2012 to 2020 to meet the policy option goal. Synthesis of biomass feedstock supply and demand is provided in F Table 38 and F Table 39 of the Appendix of this document.

F Table 31. GHG Reduction Benefit for Cellulosic Ethanol Production

Year	Cellulosic Ethanol Production (MMgal)	E85 Market Share	Cellulosic Ethanol Production for E85 (MMgal)	E85 Contribution to GHG Benefit (MMtCO2e)	Cellulosic Ethanol Production for E10 (MMgal)	E10 Contribution to GHG Benefit (MMtCO2e)	Total GHG Benefit (MMtCO2e)
2010	-	0%	-	-	-	-	-
2011	-	6%	-	-	-	-	-
2012	3.3	12%	0.4	0.0	2.9	0.0	0.0
2013	19.7	18%	3.5	0.0	16.3	0.1	0.1
2014	36.2	23%	8.5	0.1	27.8	0.1	0.2
2015	52.7	29%	15.4	0.1	37.3	0.2	0.3
2016	69.1	35%	24.2	0.2	44.9	0.2	0.4
2017	85.6	41%	35.0	0.2	50.6	0.3	0.5
2018	102.1	47%	47.7	0.3	54.4	0.3	0.6
2019	118.5	53%	62.3	0.4	56.2	0.3	0.7
2020	150.0	58%	87.6	0.6	62.4	0.3	0.9
Total							3.7

Cost Analysis

Costs estimates for this policy option are based on the difference in estimated production costs between conventional starch-based ethanol and cellulosic ethanol. The DOE EIA estimated that the cost to produce starch-based ethanol is $1.10/gal compared to $1.29/gal, or a difference of $0.19/gal (in $1998).[31] In 2006 dollars, the difference is $0.23/gal. An organic waste cost premium surcharge of $0.18/gal[32] is added to the production costs of cellulosic ethanol from forest residue as compared to starch-based ethanol production. The total costs for this option were estimated using the $0.23/gal incentive and the $0.18/gal organic waste cost premium multiplied by the annual cellulosic production by this policy option. Cost estimates are shown in F Table 32.

F Table 32. Cost Estimates of Cellulosic Ethanol Production from Forest Residue

Year	Production Cost Differential (MM$)	Waste Biomass Cost Premium (MM$)	Discounted Cost ($MM)
2010	$0	$0	$0
2011	$0	$0	$0
2012	$1	$1	$1
2013	$5	$4	$8
2014	$8	$7	$15
2015	$12	$9	$22
2016	$16	$12	$28
2017	$20	$15	$35
2018	$23	$18	$42
2019	$27	$21	$49
2020	$35	$27	$62
Total	$147	$115	$261

After discounting and leveling the costs from 2007–2020, the cost effectiveness is $70/t$CO_2$e.

Key Assumptions: Key assumptions for the GHG reductions estimate are the timeline for cellulosic ethanol production, as well as the GHG reduction benefit and production rate for cellulosic ethanol generated from forest residue biomass. For this analysis it has been assumed that cellulosic ethanol production at a commercial scale will begin in 2015. Estimates of GHG reduction benefit and production rates specific to forest residue feedstocks are not yet available and values used for this analysis are based on best available estimates from the GREET model (v1.7). Key assumptions for the cost analysis are the incremental cost of production of cellulosic

[31] DOE EIA analysis can be found at www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed January 2007.

[32] California Energy Commission (CEC). 2001. Costs and Benefits of a Biomass-to-Ethanol Production Industry in California. March 2001. Available at: http://www.energy.ca.gov/reports/2001-04-03_500-01-002+002A.PDF

ethanol from forest residue relative to starch based ethanol. Cost estimates specific to cellulosic ethanol production from forest residue feedstocks are not yet available.

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050)

2035: Use 6.2 million tons of biomass (both forest and agriculture sources) to produce 500 million gallons of biofuels and chemicals per year.

2050: Use 12.5 million tons of biomass (both forest and agriculture sources) to produce 1 billion gallons of biofuels and chemicals (roughly 1/3 of Washington State current consumption) per year.

Job Creation: Production of 250 million gallons per year would require construction of 3 – 5 biorefineries, each with the potential of employing approximately 200 – 300 people. Generally there is a multiplier of at least 2 outside jobs directly supporting each employee of the manufacturing facility. The ratio for indirect jobs (e.g. stores and restaurants) can be as high as 6 to 1.

Reduced Fuel Import Expenditures: Production of biofuels would directly reduce fuel import expenditures. Each gallon of ethanol would roughly offset 2/3 a gallon of petroleum that is imported into the state. If fuel conservation efforts limit gasoline consumption to current levels it is conceivable that one-third of Washington gasoline use be displaced by ethanol by 2050.

Key Uncertainties

There are uncertainties both in regards to the quantitative analysis in this option and in the general potential for developing a significant biofuels industry in Washington State.

Quantification of the GHG savings and cost per $MtCO_2e$ require estimates of GHG emissions per gallon of ethanol produced from woody biomass as compared to the emissions from ethanol produced from corn. Rigorous calculations of GHG emissions for producing ethanol from wood have yet to be done, so the estimates in this option were based on the more studied agricultural residue. Even for agricultural residue, the estimated GHG emission savings can vary widely, with some estimates showing that use of cellulosic material to produce ethanol can reduce GHG emissions by 90% over that of corn ethanol. A conservative life cycle estimate was used for this analysis because of the rigor applied to the calculations.

Estimates of the costs to produce a gallon of ethanol from corn or cellulosic feedstock are also uncertain. The cost of producing ethanol from corn is considerably higher now than the cost used in the analysis as a result of a sharp increase in corn costs. An accurate cost of producing cellulosic ethanol cannot be calculated at this time because there are no commercial scale processes producing ethanol.

There are also uncertainties with regard to the potential for developing a significant biofuels in Washington State. Some of these uncertainties include:

- Technical feasibility to economically produce biofuels from Washington State biomass
- Long term availability of biomass, especially from Federal lands. Price of biomass must remain reasonably low (~$50/ton) if biofuels industry is to be profitable.

- Production of biofuels from other regions of the nation and world with lower biomass cost could make it difficult to develop a viable local biofuels industry.

Additional Benefits and Costs

Additional benefits of this option center on creation of rural jobs and providing economic incentives to remove excess biomass for improved forest health.

Fuels with high ethanol content may require a new distribution network or substantial modifications to the pipelines currently used for gasoline.

Feasibility Issues

The technology to produce ethanol, or other fuels, from cellulosic biomass in a cost effective manner is still being developed. All indications are that a viable process can be developed. Biomass availability will be required to assure long-term supply for investment in biofuels production. Distribution infrastructure issues may also impact feasibility.

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

F-8 Expanded Urban and Community Forests

Mitigation Option Description

This policy option seeks to establish and maintain a net increase of urban and community forest in Washington. Tree planting and maintenance in urban and suburban areas has multiple benefits, including reducing greenhouse gas emissions due to energy conservation (primarily reduced demand for cooling in hot weather), offsetting greenhouse gas emissions due to enhanced C sequestration, and reducing urban sprawl by providing desirable living spaces.

Other benefits of urban and community forests (i.e. improving air quality, reducing storm water runoff, improving aesthetics) make it a highly desirable community investment for reasons beyond the benefits to climate change.

Mitigation Option Design

Goals: By the year 2020, enable Washington's local governments, utilities and large urban landowners to protect, plant and maintain an additional 3 million trees.

Goals past 2020 are articulated but not quantified: by 2035, protect, plant and maintain 6 million trees, and by 2050, protect, plant and maintain 12 million trees. Achieve or exceed prescribed municipal canopy goals for all cities by 2050.

Timing: See "goals" above. Also dependent on funding available and timing of The Climate Registry for development/adoption of urban forest greenhouse gas reporting protocols.

Suggested municipal canopy goals:[33]

West of the Cascades
For metropolitan areas east of the Mississippi and in the Pacific Northwest

Average tree cover counting all zones	40%
Suburban residential zones	50%
Urban residential zones	25%
Central business districts	15%

[33] http://www.americanforests.org/resources/urbanforests/treedeficit.php

East of the Cascades
For metropolitan areas in the Southwest and dry West:

Average tree cover counting all zones	25%
Suburban residential zones	35%
Urban residential zones	18%
Central business districts	9%

Coverage of parties: Affected parties, end users--Municipalities and local governments, utilities, large urban/suburban landowners, private business and homeowners.

Implementing parties--DNR, CTED, DOT, local governments.

Other: A healthy, dense urban canopy has enhanced ability to:

- conserve energy
- reduce greenhouse gas emissions
- offset green house gases (and tapping emerging carbon markets)
- benefit healthy neighborhoods and business districts, and
- reduce sprawl

Trees of the urban forest modify climate and conserve building-energy use in three principal ways:

- Shading— reduces the amount of radiant energy absorbed and stored by built surfaces.
- Transpiration — converts moisture to water vapor and thus cools by using solar energy that would otherwise result in heating of the air.
- Wind speed reduction — reduces the infiltration of outside air into interior spaces and conductive heat loss where thermal conductivity is relatively high (e.g. glass windows)[34]

Urban Forests can reduce atmospheric CO_2 in two ways:

Trees directly sequester CO_2 as woody and foliar biomass while they grow, and

Trees near buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production. [6]

[34] Mcpherson, E.G.; Maco, S.E.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; VanDerZanden, A.M.; Bell, N.; 2002. **Western Washington and Oregon Community Tree Guide: Benefits, Costs and Strategic Planting**. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. http://www.fs.fed.us/psw/programs/cufr/products/5/CUFR_164_Western_WA_OR_Tree_Guide.pdf

Communities with healthy, robust trees can concentrate consumers and residents:

- Consumers shop longer, more frequently and are willing to pay more for goods/services in well-landscaped business districts
- Well maintained trees maintain the "curb-appeal" of properties
- Treed cities are desirable communities with stronger communities, less crime, cleaner air, less noise, more wildlife and improved aesthetics. [6]

"Why Set Tree Canopy Goals?[35]

Tree cover is directly related to environmental quality. Maintaining a robust enough tree cover to functions as green infrastructure reduces the need and expense of building infrastructure to manage air and water resources. Local agencies can use CITYgreen software to calculate the environmental and economic values of the ecosystem services that trees provide. American Forests' intent is to help communities calculate the value of their trees so that city leaders can make make better decisions about integrating "green" into their urban infrastructure."

Implementation Mechanisms:

Energy Conservation/Emissions Reduction

Incentivize or require local ordinances that plant the right trees in the right place to conserve energy (heating and cooling) in new homes and businesses.

Incentivize & educate home and business owners to position appropriate trees in the best locations around buildings to conserve maximum energy (heating and cooling).

Incentivize or require local municipalities to develop and implement forest management plans that include goals and strategies for increasing number of trees to reduce "heat island" effect and reduce heating/cooling costs around public buildings, businesses and homes.

Require/encourage urban forest byproducts to be managed to maximize carbon sequestration and GHG reduction potential (e.g., use for bioenergy or in durable wood products).

Carbon Sequestration

Establish statewide inventory and baseline of community and urban forests in WA.

Require state to begin using emerging Urban Forest Greenhouse Gas reporting protocols for sectors or projects voluntarily "reporting" to DNR.

Establish sub-goals for maintenance of existing trees and forests, additionality of protecting trees otherwise slated for removal and preparation of planting sites—esp. removal of invasive species.

Enable municipalities, utilities, and large urban landowners to help meet that goal through state "seed grants."

Require "reporting" to DNR for eligibility to "seed grants".

Position Washington's additional urban trees for carbon offset markets.

[35] http://www.americanforests.org/resources/urbanforests/treedeficit.php

Establish disincentives (monetary and civil penalties) for violations of local ordinances or permits requiring tree retention in development projects.

Consider impact fees and or 4:1 tree mitigation requirements for trees lost from development or other permanent conversion of forested land.

Fees collected above the local component go into a "seed grant" account.

Averting Sprawl – Livable Cities

Transportation Mitigation

Establish/require tree-lined streets protocols based on road traffic capacity

Establish greenways and urban forest corridors

Require "mitigation" for deforestation and traffic impacts

Implement within urban growth boundaries. Developers to replace trees either within the UGB or by establishing trees outside the UGB and putting them under a conservation easement.

Establish Highway Greenway stem/easement requirements for WSDOT and other road builders.

Transfer of Development Rights

Prioritize Municipalities utilizing Transfer of Development Rights from working exurban forestland to secure seed grants

Require local governments to establish urban forestry (stem and canopy) goals and strategies in their comprehensive plans—as part of larger greenhouse gas reduction plans.

Establish Community Forests of Long Term Significance.

Related Policies/Programs in Place

RCW 76.15 – enabling legislation for the state's Community and Urban Forestry Program and Community Forest Council. http://apps.leg.wa.gov/RCW/default.aspx?cite=76.15

Types(s) of GHG Reductions

GHG reductions stem from two sources: (1) avoided fossil fuel use for energy due to wind protection and reduced demand for cooling, and (2) direct C sequestration in tree biomass.

Estimated GHG Savings (in 2020) and Costs per $MtCO_2e$

			Reductions		($MMtCO_2e$)*		
	Policy	**Scenario**	**2012**	**2020**	**Cumulative Reductions (2008–2020)**	**NPV (2008–2020) $ millions**	**Cost-Effective-ness $/$tCO_2$**
F-8	Urban and Community Forests	Plant 3 million trees by 2020	0.07	0.2	1.4	-165	-122

Data Sources: Information about current numbers of trees in urban forest and annual C storage in urban trees in WA from: Nowak et al., USDA Forest Service, Northern Research Station, Urban Forest Effects on Environmental Quality State Summary data for Washington http://www.fs.fed.us/ne/syracuse/Data/State/data_WA.htm. Fossil fuel reductions through reduced demand for cooling and protection from wind from: McPherson and Simpson (1999). Carbon Dioxide Reduction Through Urban Forestry, USFS PSW-GTR-171. Data on costs of tree planting and maintenance from: McPherson, E.G.; Maco, S.E.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; VanDerZanden, A.M.; Bell, N.; 2002. Western Washington and Oregon Community Tree Guide: Benefits, Costs and Strategic Planting. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station. http://www.fs.fed.us/psw/programs/cufr/products/5/CUFR_164_Western_WA_OR_Tree_Guide.pdf

Quantification Methods:

Direct carbon sequestration in urban trees

To achieve a cumulative net increase of 3 million trees in WA by 2020, a linear rate of increase in tree planting was assumed, with 230,769 additional trees/ year planted in WA communities beginning in 2008 and assuming this rate stays constant through to 2020 (230,772 trees in 2020 to get to 3 million trees even). Annual C sequestration per urban tree is calculated as 0.006 t C per tree per year, based on statewide average data reported by the USDA Forest Service. This is the average annual per-tree C sequestration value when the total estimated urban forest C accumulation in WA (572000 t C/ yr) is divided by the total number of urban trees in WA (93.272 million). Since trees planted in one year continue to accumulate C in subsequent years, annual C sequestration in any given year is calculated as the sum of C stored in trees planted each year, plus the sequestration by trees that were planted in prior years. F Table 33 describes the annual and cumulative C storage in urban tree biomass under this option.

F Table 33. C sequestered by urban trees between 2008 and 2020.

	Trees planted this year	Trees planted in previous years	Carbon sequestered (MtC/yr)	Carbon Sequestered ($MMtCO_2e$ /yr)
2008	230,769		1,415	0.01
2009	230,769	230,769	2,830	0.01
2010	230,769	461,538	4,246	0.02
2011	230,769	692,307	5,661	0.02
2012	230,769	923,076	7,076	0.03
2013	230,769	1,153,845	8,491	0.03
2014	230,769	1,384,614	9,907	0.04
2015	230,769	1,615,383	11,322	0.04
2016	230,769	1,846,152	12,737	0.05
2017	230,769	2,076,921	14,152	0.05
2018	230,769	2,307,690	15,567	0.06
2019	230,769	2,538,459	16,983	0.06
2020	230,772	2,769,228	18,398	0.07
Cumulative total		3,000,000		0.47

Avoided fossil fuel emissions

Offsets from avoided fossil fuel use for heating and cooling are the sum of three different types of savings: avoided emissions from reduced cooling demand, avoided emissions from reduced demand for heating due to wind reduction, and enhanced fossil fuel emissions needed for heat due to wintertime shading. The magnitude of GHG savings varies by home vintage (generally the net reductions are greater in older homes). The analysis assumes that half of the trees are planted on existing homes and the other half on new homes. Estimate GHG reductions are based on calculations presented by McPherson et al. in GTR-PSW-171. For existing homes, the default distribution of homes of pre-1950, 1950-1980, and post-1980 vintages was used. For new homes, the GHG reductions associated with the newest home category (post-1980) were used.

In addition, it was assumed that 80% of the new urban trees are planted in the PNW climate region and 20% are planted in the "Northern Tier" region. These climate regions follow those presented by McPherson et al. in GTR-PSW-171. The proportions of 80% and 20% are the relative proportions of WA residents living in each half of the State. For fossil fuel reduction calculations, it is assumed that all planted trees are medium-sized evergreens (note the McPherson coefficients are based on the effects of mature trees; applying those to this analysis may overestimate the actual near-term benefits as it will take some years before the newly planted trees reach maturity). F Table 34 describes the average GHG impact per tree of planting urban trees in the Pacific Northwest and Northern Tier climate regions. These values assume medium-sized evergreen trees, and assume average tree distribution around buildings (i.e. these fossil fuel reduction factors are average for existing buildings, do not necessarily assume that trees are optimally placed around buildings to maximize energy efficiency). These factors are also dependent on the fuel mix (coal, hydroelectric, nuclear, etc.) in the regions of interest, and are thus likely to change if the electricity mix changes from its 1999 distribution.

F Table 34. Fossil fuel savings per tree per year (from McPherson et al. GTR-171) in Northern Tier and PNW Communities.

Northern Tier (Eastside)					
Housing vintage	shade-cooling (tCO_2e/yr)	shade-heating (tCO_2e/yr)	wind-heating (tCO_2e/yr)	net effect (tCO_2e/yr)	Default Vintage distribution
pre-1950	0.01	-0.02	0.10	0.09	45%
1950-1980	0.01	-0.01	0.07	0.06	42%
post-1980	0.01	-0.02	0.09	0.08	13%
Weighted Average (tCO_2e/yr)					0.08
Weighted Average ($MMtCO_2e/yr$)					7.5717E-08
PNW Tier (Westside)					
Housing vintage	shade-cooling (tCO_2e/yr)	shade-heating (tCO_2e/yr)	wind-heating (tCO_2e/yr)	net effect (tCO_2e/yr)	Default Vintage distribution
pre-1950	0.00	-0.03	0.08	0.05	30%
1950-1980	0.00	-0.02	0.06	0.04	58%
post-1980	0.00	-0.02	0.04	0.02	12%
Weighted Average (tCO_2e/yr)					0.04
Weighted Average ($MMtCO_2e/yr$)					4.2682E-08

RCI-3 contains "improved community planning" as an element. Shading from tree planting is not explicitly quantified in that option, though it is possible that some overlap between these two options exists. Final GHG reduction summaries will take into account estimated overlap of RCI-3 and F-8 in terms of avoided fossil fuel emissions from efficiency gains due to planting trees, to avoid double-counting.

GHG emission reductions from avoided fuels were calculated by multiplying the number of trees planted by the relevant emission reduction coefficients, assuming 80% of trees are planted on the Westside and half of those are planted on new construction, while the other half is planted on existing homes. Likewise, it is assumed that 20% of trees are planted on the eastside with the same split between new and existing homes.

Overall GHG benefit of urban tree planting

Total GHG benefits are calculated as the sum of direct C sequestration plus fossil fuel offset from reduced cooling demand and wind reduction (F Table 35).

F Table 35. Overall GHG benefits of planting 3 million urban trees in WA by 2020.

	Trees planted this year	Trees planted in previous years	GHG sequestered ($MMtCO_2e/yr$)	GHG avoided ($MMtCO_2e/yr$)	overall GHG savings ($MMtCO_2e/yr$)
2008	230,769		0.01	0.01	0.01
2009	230,769	230,769	0.01	0.02	0.03
2010	230,769	461,538	0.02	0.03	0.04
2011	230,769	692,307	0.02	0.04	0.06
2012	230,769	923,076	0.03	0.05	0.07
2013	230,769	1,153,845	0.03	0.06	0.09
2014	230,769	1,384,614	0.04	0.07	0.10
2015	230,769	1,615,383	0.04	0.08	0.12
2016	230,769	1,846,152	0.05	0.09	0.13
2017	230,769	2,076,921	0.05	0.10	0.15
2018	230,769	2,307,690	0.06	0.11	0.16
2019	230,769	2,538,459	0.06	0.12	0.18
2020	230,772	2,769,228	0.07	0.13	0.19
cumulative totals		3,000,000	0.47	0.88	1.35

Cost analysis

Economic costs of tree planting are calculated as the sum of tree planting and annual maintenance, including the costs of program administration and waste disposal. Economic benefits of tree planting include the cost offset from reduced energy use, as well as the estimated economic benefits of services such as provision of clean air, hydrologic benefits such as stormwater control, and aesthetic enhancement (McPherson et al. 2002). Since economic costs data were only available for the PMNW region, it is assumed that economic costs and benefits of urban tree planting in Eastside communities are the same as the economic costs and benefits of tree planting in Westside communities.

The net cost of planting and maintenance for the first three years in the PNW region is assumed to be $125. This is the midpoint of estimated costs of $50 to 200 (G. McPherson, pers. comm. with H. Packard), and is also consistent with average planting cost ($125) calculated by

McPherson et al. (2002). After the first three years the annual maintenance cost per tree is estimated as $16.30 per tree (McPherson et al. 2002), which is the average public/ private maintenance cost for a medium-sized tree. F Table 36 gives estimated economic costs for this option in WA.

F Table 36. Costs of planting and maintenance for urban tree planting efforts in WA, 2008-2020.

	Trees planted this year	Trees planted in previous years	Cost of planting + three years maintenance	Annual maintenance cost after 3 years	Annual cost ($$/yr)
2008	230769		$28,846,125.00		$28,846,125.00
2009	230769	230769	$28,846,125.00		$28,846,125.00
2010	230769	461538	$28,846,125.00		$28,846,125.00
2011	230769	692307	$28,846,125.00	$3,761,534.70	$32,607,659.70
2012	230769	923076	$28,846,125.00	$7,523,069.40	$36,369,194.40
2013	230769	1153845	$28,846,125.00	$11,284,604.10	$40,130,729.10
2014	230769	1384614	$28,846,125.00	$15,046,138.80	$43,892,263.80
2015	230769	1615383	$28,846,125.00	$18,807,673.50	$47,653,798.50
2016	230769	1846152	$28,846,125.00	$22,569,208.20	$51,415,333.20
2017	230769	2076921	$28,846,125.00	$26,330,742.90	$55,176,867.90
2018	230769	2307690	$28,846,125.00	$30,092,277.60	$58,938,402.60
2019	230769	2538459	$28,846,125.00	$33,853,812.30	$62,699,937.30
2020	230772	2769228	$28,846,500.00	$37,615,347.00	$66,461,847.00
cumulative totals		3000000	$375,000,000.00	$206,884,408.50	$581,884,408.50

The net cost savings (economic benefit) of -$40.58 per tree per year is calculated from McPherson et al. (2002) as the average of small, medium, and large trees under public and private management. This economic benefit assumes trees are planted on west side in optimal position for shading in a residential yard setting in PNW.

Net economic costs for this option are calculated as the difference between costs of planting + maintenance and economic benefit realized by urban trees. Negative costs therefore refer to net economic benefits, where estimated benefits exceed overall costs. Overall economic results suggest that implementation of this option in WA has a net economic benefit of $30.8 million in 2020 (

F Table 37). This corresponds to a cumulative cost savings (or Net Present Value) of -$165 million from 2008-2020, with an estimated cost effectiveness of -$122 per ton of CO_2e.

F Table 37. Net economic costs of tree planting in WA communities, 2008-2020.

	Total $$ benefit	Net benefit (costs minus benefits)	Discounted net benefits
2008	$9,363,836.79	$19,482,288.21	$19,482,288.21
2009	$18,727,673.58	$10,118,451.42	$9,636,620.40
2010	$28,091,510.37	$754,614.63	$684,457.71
2011	$37,455,347.16	-$4,847,687.46	-$4,187,614.69
2012	$46,819,183.95	-$10,449,989.55	-$8,597,232.26
2013	$56,183,020.74	-$16,052,291.64	-$12,577,390.53
2014	$65,546,857.53	-$21,654,593.73	-$16,158,991.25
2015	$74,910,694.32	-$27,256,895.82	-$19,370,966.98
2016	$84,274,531.11	-$32,859,197.91	-$22,240,398.55
2017	$93,638,367.90	-$38,461,500.00	-$24,792,625.83
2018	$103,002,204.69	-$44,063,802.09	-$27,051,352.10
2019	$112,366,041.48	-$49,666,104.18	-$29,038,742.48
2020	$121,730,000.00	-$55,268,153.00	-$30,775,375.62

Key Assumptions: see quantification methods above.

Contribution to Other Goals

Contribution to Long-term GHG Emission Goals (2035/2050): Tree canopy goals are articulated to this time period. GHG reductions will be realized as long as urban canopy is healthy, and trees are replaced as mortality occurs.

Job Creation: Possible as urban tree planting and management is enhanced.

Reduced Fuel Import Expenditures: Applicable as fuel demand for heating and cooling is reduced due to shading and wind protection.

Key Uncertainties

The GHG reductions associated with shading effects and heating/cooling demand may be overestimated for two reasons. The CO_2 reduction factors are for mature trees and during the timeframe of this analysis most trees will still be relatively young and thus not yet providing maximum shade benefits. In addition, the analysis assumes all 3 million trees will be planted around buildings in such a way to provide additional shade. Urban trees can be planted in a variety of settings, including parks and along streets, where shading effects may not be relevant.

Additional Benefits and Costs

Ecosystem benefits of urban trees beyond carbon sequestration include clean air, clean water, and stormwater protection. Aesthetic benefits lead to improved property values and potential property tax revenue. Improved aesthetic quality of urban settings reduces sprawl and encourages dense settlements, which reduces need for transportation fuel and improves overall quality of life.

Feasibility Issues

None cited

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD

Appendix
Biomass Feedstock Supply Available for Bioenergy Production in Washington

F Table 38. Synthesis of Potential Biomass Supply and Demand

	2012	2020	Notes
Supply	Mt/yr	Mt/yr	
Logging Residue	1,400,000	1,400,000	Midpoint between DOE/WSU and NREL estimates
Mill Residue	91,000	91,000	Unused primary, plus secondary NREL estimates; most of the primary is already used on site
Paper Sludge	180,00	180,000	Kerstetter, J.D et al. 1996
Forest Pre-Commercial Thinning	458,000	458,000	DOE current levels
Forest Fuel Treatments	3,700,000	3,700,000	USFS estimate of total treatable forestlands; F-1 would also contribute to this supply
Total	5,649,000	5,649,000	
Demand			
F-6	113,970	523, 345	Based on biomass fuel use (F-6: F Table 23)
F-7	36,500	1,500,000	Based on F-7 goal statement
Total	150,470	2,023,345	
Biomass Balance (Supply minus Demand)	5,498,530	3,625,655	

F Table 39. Results of Literature Review and Preliminary Analysis of F-1

Source	DOE – WSU 2005	NREL 2005	USFS 2004	Kerstetter, J.D et al. 1996	F-1 Analysis	Western Gov. Report
Logging Residue	1.7 million dry Mt/yr	1.0 million dry Mt/yr	-			1.4 million dry Mt
Mill Residue	4.8 million dry Mt/yr	Primary: Total: 5.6 million dry Mt/yr Unused: 6,000 dry Mt/yr Secondary: 85,000 dry Mt/yr	-			
Paper Sludge				180,000 dry Mt/yr		
Current: Forest Thinnings	458,000 dry Mt/yr		-			
Potential: Forest Fuel Thinnings	-	-	Total Treatable: 3.7 million dry Mt/yr Highest Fire Risk: 630,000 dry Mt/yr Highest and Moderate Fire Risk: 2.4 million dry Mt/yr		1.2 million dry Mt/yr (373,000 acres treated by 2020, could produce over 15 million dry tons of biomass)[36]	

Data sources and calculation methodologies: DOE-WSU. 2005. Biomass Inventory and Bioenergy Assessment: An Evaluation of Organic material Resources for Bioenergy Production in Washington State. Publication No. 05-07-047. http://www.ecy.wa.gov/pubs/0507047.pdf

State inventory of biomass available by county

Logging Residue: Residue left behind in forest land after commercial logging

Data Source: Forest logging residue values were obtained by taking the annual county level timber harvest for 2002 and multiplying each of the categories (national forest, public forest, and private forest) (WSDNR, 2002) by a residue factor as supplied by Howard (1981)

[36] Assumes: no prescribed burning; 45% of biomass carbon is removed: average carbon density of forest is 47.11 tons C/yr (eastside average from WA Inventory and Forecast).

Do more accurate inventories exist?

Mill Residue: Bark/wood residue from sawmills, pulp mills, shake/shingle operations, whole log chippers, veneer plywood factories, post/pole/piling operations and log export

Data Source: Mill residue values were obtained from a 2002 mill waste report given in dry tonnage by region which was then cross referenced against the number of mills within each county so that an average disbursement of this regional mill tonnage could be given for each county (WDNR, 2002).

Forest Thinnings: Current

Data source: Sum of state silvicultural burn data (WADNR, 2004) and pre-commercial thinning data from the Forest Inventory and Analysis Timber Product Output (TPO) Database (Forest Service, 2004).

(USFS 2003) Rummer, B. et al. 2003. A Strategic Assessment of Forest Biomass and Fuel Reduction Treatments in Western States. United States Department of Agriculture Forest Service Research and Development.

Data Source: Estimates are based on examining total treatable timberlands defined as those forestlands that produce greater than 20 ft3/year of merchantable wood , not reserved, not at high elevation, are within 15 miles of major transportation infrastructure, and are suitable "operations will not produce irreversible damage to soil or water resources".

Fire risk was evaluated based on modeled estimates of the Stand Density Index and Fire Regime Condition Class of forestlands. Fire Regime Condition Class (FRCC) is a measure of how much a forest has departed from natural wildland fire conditions. Forestlands at moderate fire risk (Class 2) have fire regimes that have been moderately altered from the historical range and restoration treatments such as fire or mechanical treatments would be required to begin managing a more natural fire cycle. In forestlands at high fire risk (Class 3), where fire regimes have been significantly altered and there is a high risk of losing key ecosystem components in a wildfire, mechanical treatments (i.e. thinning) are expected to be needed before the reintroduction of fire due to high fuel loading.

Estimates presented are annual volumes based on biomass removals over a 30 yr period after which time areas would need to be re-thinned. It is assumed that 30% of biomass harvested would be available for biomass energy production.

(NREL 2005) Milbrant, A. 2005.A Geographic Perspective on the Current Biomass Resource Availability in the United States. *Technical Report* NREL/TP-560-39181, December 2005

Forest Residues: Included logging residues, the unused portions of trees cut, or killed by logging, and left in the woods, and other removals.

Data Source: Forest residue data by county was derived from the USDA Forest Service's Timber Product Output database for 2002.

Primary mill residue: Composed of wood materials (coarse and fine) and bark generated at manufacturing plants (primary wood-using mills) when round wood products are processed into primary wood product

Data Source: Data by county derived from the USDA Forest Service's Timber Product Output database for 2002.

Secondary Mill Residues: Include wood scraps and sawdust from woodworking shops—furniture factories, wood container and pallet mills, and wholesale lumberyards.

Data Source: Based on values from Wiltsee 1998 which found pallet and lumber companies generate about 300 tons/year, and a small woodworking company typically generates between 5 and 20 tons/year of wood waste.

Wiltsee, G, Urban Wood Waste Resource Assessment, Appel Consultant, Inc. Valencia, CA., November, 1998.

WGA-CDEAC. 2006b. Biomass Task Force Report: Supply Addendum. Western Governors' Association's Clean and Diversified Energy Advisory Committee http://www.westgov.org/wga/initiatives/cdeac/Biomass-supply.pdf

Unused logging slash

Data Source: Estimated quantities of unused logging slash were obtained from the Timber Products Output (TPO) interactive web assessment tool maintained by the US Forest Service. Output from the TPO database in cubic feet of logging residue was converted to dry tons using a density of 25 lbs/ft3.

Forest fuel treatment & thinning biomass - Timberland

Data Source: Estimates of forest thinning biomass to be removed in order to mitigate fire hazard on timberland were obtained using the Fuel Treatment Evaluator Version 3.0.

Miles, Patrick D. Aug-04-2005. Fuel Treatment Evaluator web-application version 3.0. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. [Available only on internet: http://www.ncrs2.fs.fed.us/4801/fiadb/fte_test2/fte_test2.asp]

Forest fuel treatment & thinning biomass – Other forest land

Data Source: Other forest land is forest land other than timberland or reserved forest land. It includes forest land that is incapable of producing 20 ft3/year of merchantable wood.

Perlack, R.D. et al. 2005 Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion ton supply. Oak Ridge National Laboratory, Oak Ridge, TN 60 p. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

Primary Sawmill Residues

Data Source: Estimates of unused mill residues were obtained from the Timber Products Output database. The mill residue estimate does not so far include potential additional residues from sawlogs removed as part of forest thinning operations. http://ncrs2.fs.fed.us/4801/fiadb/rpa_tpo/wc_rpa_tpo.ASP

Kerstetter, J.D., K. Lyford., and L. Lynd. 1996. Assessment of Pulp and Paper Sludge for Conversion to Ethanol. Washington State Energy Office. July Monthly Technical Status Report; Subcontract # ACG-6-15177-01

Estimate of dry tons per year of paper sludge available in Washington 180,000 Mt (200,000 dry tons) are based on the above report and personal communication from Llewellyn Matthews (11 November 2007).